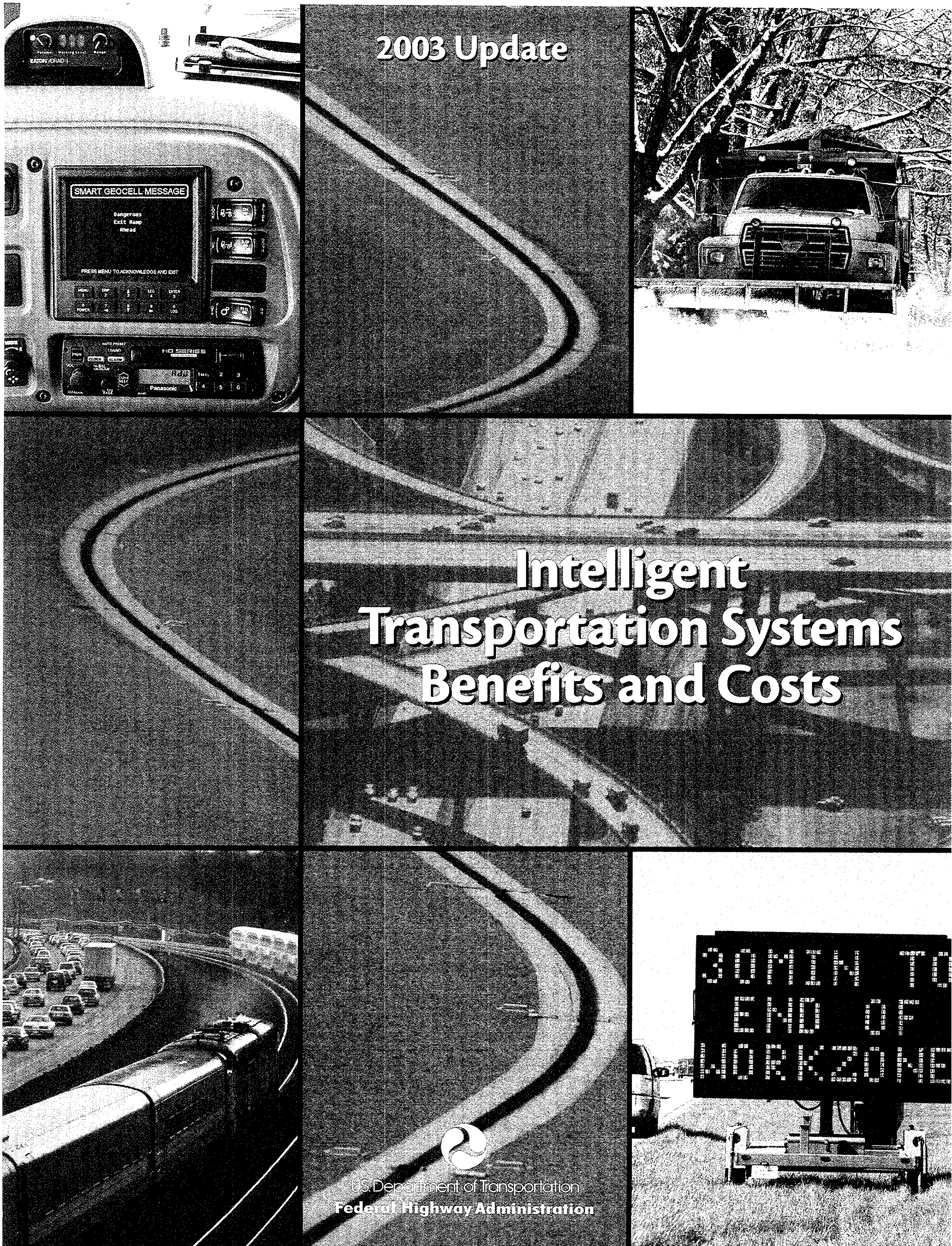
2003 Update

Intelligent Transportation Systems Benefits and Costs



U.S. Department of Transportation
Federal Highway Administration

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Intelligent Transportation Systems Benefits and Costs

2003 Update

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16. Abstract

The increasing demand for travel by highway and public transit in the United States is causing the transportation system to reach the limits of its existing capacity. Intelligent Transportation Systems (ITS) can help ease this strain through the application of modern information technology and communications. This report is a continuation of a series of reports providing a synthesis of the information collected by the United States Department of Transportation's ITS Joint Program Office on the impact that ITS projects have on the operation of the surface transportation network. New in this 2003 report is the inclusion of cost information for representative ITS deployments; previous reports contained only benefits information. Information in this report is drawn from the ITS Benefits and Unit Costs Database, a regularly updated repository of such information, available on the Internet at **www.benefitcost.its.dot.gov**. The report presents material from the database that describes the impacts and costs of the intelligent transportation infrastructure as well as intelligent vehicle applications.

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Preface

For the first time, the U.S. Department of Transportation (DOT) is presenting in one document benefits and costs information for Intelligent Transportation Systems (ITS) implementations. *Intelligent Transportation Systems Benefits and Costs 2003 Update* represents a culmination of DOT's active 10-year data collection on the impact of ITS projects on surface transportation and the cost of implementing them. This compendium builds on previous ITS benefits reports, and refers the reader to information sources.

As a public service, DOT also sponsors a regularly updated online ITS Benefits and Unit Costs Database at **www.benefitcost.its.dot.gov**, which gives transportation professionals the information they need about benefits and costs of ITS implementations and services. The database also gives researchers information on ITS areas where further analysis may be required.

The printed 2003 Update (FHWA Report FHWA-OP-03-075) can be ordered by writing to **itspubs@fhwa.dot.gov**. It can be viewed on DOT's ITS Electronic Document Library at **www.its.dot.gov/itsweb/welcome.htm** as document No. 13772.

Not all ITS efforts initiated by states, local governments, and private enterprises are documented in the 2003 Update or in the database. We encourage readers who are aware of ITS benefits and costs information from these and other sources to let us know about them by using the online database or by sending reference documents to:

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Executive Summary

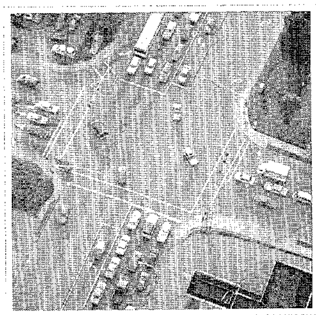
The increasing demand for travel by highway and public transit in the United States is causing the transportation system to reach the limits of its existing capacity. Intelligent Transportation Systems (ITS) can help ease this strain through the application of modern information technology and communications. ITS include a wide collection of applications, from 511 telephone traveler information systems to freeway ramp metering systems and electronic transit fare payment systems. In order to apply ITS services most effectively, it is important to understand their benefits and costs. The diverse array of ITS applications available can address a variety of transportation problems. Some applications provide more cost-effective benefits than others, and as technology evolves, the available choices change. The costs of these technology investments—not only the first-time, initial costs, but the costs to operate and maintain them—are of interest to transportation agencies.

This report is a continuation of a series of reports providing a synthesis of the information collected by the United States Department of Transportation's (U.S. DOT) ITS Joint Program Office (JPO) on the impact that ITS projects have on the operation of the surface transportation network. New in this 2003 report is the inclusion of cost information for representative ITS deployments; previous reports contained only benefits information.

Information in this report is drawn from the ITS Benefits and Unit Costs Database, a regularly updated repository of such information, available on the Internet at **www.benefitcost.its.dot.gov**. The report presents material from the database that describes the impacts of the intelligent transportation infrastructure as well as intelligent vehicle applications. The majority of published evaluations of ITS implementations document positive impacts on the transportation system, and the assessments provided in this report reflect this fact. However, every attempt has been made to incorporate positive, negative, and neutral findings. A small number of negative findings appear in this report; for example, Section 2.6 documents increases in crashes at toll plazas with electronic toll collection, likely due to driver uncertainty regarding plaza configuration and the variations in the speeds of vehicles within the plazas. This report also documents a few evaluations which found that an ITS implementation did not have an impact on a particular measure of effectiveness, including two studies that found traveler information does not have a significant impact on capacity, while it does reduce traveler delay. Mixed results are also noted in the few instances where studies have found both positive and negative impacts in a given area. There is a continuing need for ongoing evaluation of ITS, as indicated by the large number of application areas within this report for which there are not enough evaluation data to make an assessment of the system's impact on many of the relevant performance measures.

The remainder of the Executive Summary provides representative samples of the information in the main body of the report. The body of this report includes additional detail on the impacts and costs of many applications within the wide variety represented by the major ITS program areas. The concluding section of this report contains a summary of the availability of benefits and costs data for the various ITS applications and points out the gaps that still remain.

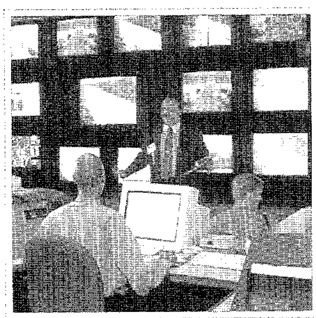
The following pages contain brief descriptions of the 16 ITS program areas discussed, as well as highlights of the benefits and costs information available for each.



Arterial Management Systems

Arterial management systems manage traffic along arterial roadways, employing traffic detectors, traffic signals, and various means of communicating information to travelers.

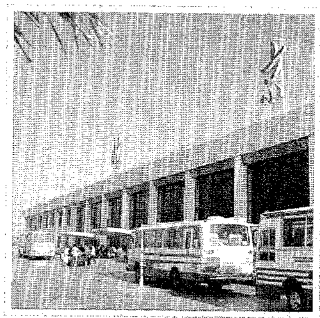
Benefits		
Studies from 6 cities in Canada, Brazil, Spain, and Scotland indicated delay reductions from 5% - 42% after installation of adaptive signal control systems.[1,2,3,4,5]		
Costs		
System Cost	Arlington County, Virginia, Department of Public Works, Traffic Engineering Division, recently brought 65 intersections (expandable to 235) under an adaptive signal control system. The costs included software, hardware, roadside equipment, cabling, mobilization and maintenance of traffic, installation, training, maintenance and test equipment, and system documentation.[6]	Project cost: **$2.43** million (2001)



Freeway Management Systems

Freeway management systems employ traffic detectors, surveillance cameras, and other means of monitoring traffic flow on freeways to support the implementation of traffic management strategies such as ramp meters, lane closures, and variable speed limits (VSL).

Benefits		
A study of the six-week shutdown of the ramp meters in Minneapolis-St. Paul, Minnesota, found that ramp meters were responsible for: • a 21% crash reduction, • a 10% increase in the volume of traffic accommodated by area freeways, • and a 22% decrease in travel times.[7] Traveler opinions of the system improved with the implementation of a modified operating strategy after the shutdown. The new operating strategy used fewer ramp meters, operating for a shorter period of time each day, with faster metering rates. Support for complete shutdown of the system dropped from 21% prior to the shutdown to just 14% of survey respondents after the system modifications.[8] A simulation study of the system found 2 - 55% fuel savings for vehicles traveling along two corridors in the city, under varying levels of travel demand.[9]		
Costs		
System Cost	Colorado DOT (CDOT) has implemented ramp metering to regulate the flow of traffic onto freeways as part of the T-REX (Transportation Expansion) project.[10,11]	Cost: **$50,000** for each site installed with controller (2001)



Transit Management Systems

Transit ITS services include surveillance and communications, such as automated vehicle location (AVL) systems, computer-aided dispatch (CAD) systems, and remote vehicle and facility surveillance cameras, which enable transit agencies to improve the operational efficiency, safety, and security of the nation's public transportation systems.

Benefits		
The GPS-based AVL system in Denver, Colorado, rated very well with Regional Transportation District (RTD) dispatchers. Operators and dispatchers were able to communicate more quickly and efficiently. Approximately 80% of dispatchers found the system "easy" or "very easy" to use, and about 50% of operators and street supervisors felt likewise. The system succeeded in improving bus service by decreasing the number of passenger late arrivals by 21%.[12]		
Costs		
System Cost	The Denver RTD installed the AVL system on its 1,355-vehicle fleet. Capital costs include system software, dispatch center hardware, in-vehicle hardware, field communication equipment, initial training, and planning and implementation.[12]	Capital cost: **$10.4** million (approx.) Annual Operations & Maintenance (O&M) cost: **$1.9** million (approx.) (1997)

Incident Management Systems

Incident management systems can reduce the effects of incident-related congestion by decreasing the time to detect incidents, the time for responding vehicles to arrive, and the time required for traffic to return to normal conditions. Incident management systems make use of a variety of surveillance technologies, often shared with freeway and arterial management systems, as well as enhanced communications and other technologies that facilitate coordinated response to incidents.

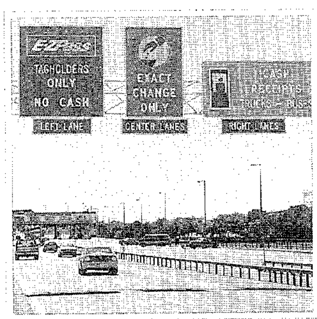
Benefits		
A study of the Coordinated Highways Action Response Team (CHART) in Maryland found that the system reduced average incident duration 57% in 2000 and 55% in 1999.[13] Delay savings identified in studies of systems in Minnesota, Colorado, and Indiana yield benefits of $1.2 - $1.8 million/yr.[14, 15, 16] Motorist assistance patrols, an important component of many incident management systems, are well-received by the public. The Virginia Department of Transportation has published hundreds of "thank you" letters received regarding its Safety Service Patrol.[17]		
Costs		
System Cost	Dane County, Wisconsin, implemented an interagency dispatch and reporting coordination system to improve response to incidents and emergencies. Police vehicles are equipped with on-board computers used to transmit incident data to a central dispatching database.[18]	Cost per vehicle: **$8,000-$10,000**

Emergency Management Systems

ITS applications in emergency management include hazardous materials management, the deployment of emergency medical services, and large- and small-scale emergency response and evacuation operations.

Benefits
The LifeLink project in San Antonio, Texas, enabled emergency room doctors to communicate with emergency medical technicians (EMTs) using 2-way video, audio, and data communications. EMTs and doctors had mixed opinions about the system; however, it was expected that this technology would have more positive impacts in rural areas, where transit times to emergency rooms are generally longer.[19]

Costs		
System Cost	To overcome the lack of shared communications among Emergency Operations Centers (EOCs) in the Seattle, Washington, metropolitan area, the Smart Trek project purchased and distributed to each EOC communications equipment that operated on the same frequency. The project cost included the purchase of sixteen 800 MHz radios, three repeater station upgrades, other equipment, and planning and development labor costs.[20]	Cost: **$151,700** (1998) Annual O&M cost: **$2,860** (1998)

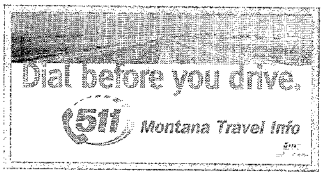


Electronic Payment Systems

Electronic payment systems employ various communication and electronic technologies to facilitate commerce between travelers and transportation agencies, typically for the purpose of paying tolls and transit fares.

Benefits
Evaluation of the smart card electronic payment system in Ventura, California, indicated potential savings of $9.5 million per year in reduced fare evasion, $5 million in reduced data collection costs, and $990,000 in transfer slip elimination.[21]

Costs		
System Cost	The Ventura County Transportation Commission, in California, implemented an electronic fare payment system on its buses. The "Go Ventura" card allows transit riders to use a smart card for fare payment. The card can be used on buses run by the county's six transit systems.[22]	Project cost: **$1.7 million** (2001)



Traveler Information

Traveler information applications use a variety of technologies, including Internet websites, telephone hotlines, as well as television and radio, to allow users to make more informed decisions regarding trip departures, routes, and mode of travel. Ongoing implementation of the designated 511 telephone number will improve access to traveler information across the country.

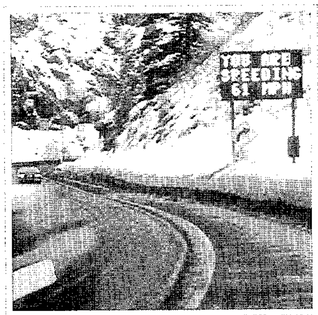
Benefits
In a 1999 survey, individuals using the Advanced Regional Traffic Interactive Management and Information System (ARTIMIS) telephone traveler information service in the Cincinnati, Ohio, area rated the system highly: • More than 99% of those surveyed said they benefited by avoiding traffic problems, saving time, reducing frustration, and arriving at destinations on time. • 81% said they had recommended the service to someone else.[23]

Costs		
System Cost	Nebraska's Department of Roads and the Nebraska State Patrol have teamed up to deploy a statewide 511 Traveler Information system. The new 511 system replaces the toll-free weather and road condition system formerly operated by the State Patrol.[24]	Initial cost: **$120,000** (2001) Estimated annual O&M cost: **$110,000** (2001)

Information Management

ITS information management supports the archiving and retrieval of data generated by other ITS applications and enables ITS applications that use archived information. Decision support systems, predictive information, and performance monitoring are some ITS applications enabled by ITS information management. In addition, ITS information management systems can assist in transportation planning, research, and safety management activities. As deployment of ITS information management matures, quantitative information on the benefits of these systems should become more readily available.

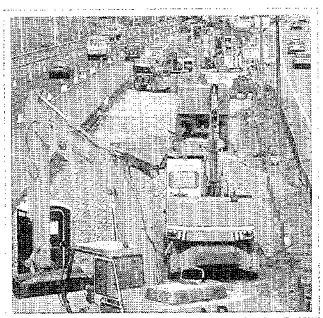
Costs		
System Cost	The total cost of the Nevada DOT Freeway and Arterial System of Transportation (FAST) central system software design and development is approximately $4.225 million. The software will provide a fully automated freeway management system, plus the capability to receive, collect, archive, summarize, and distribute data generated by FAST. Of the $4.225 million, the cost to develop the design for the implementation of the Archived Data User Service (ADUS) for FAST was approximately $225,000. This cost included needs assessment, update of functional requirements, update of the regional architecture for the Las Vegas area, and system design.[11]	Software design and development cost: **$4.225** million (2001) ADUS design cost: **$225,000** (2001)



Crash Prevention & Safety

Crash prevention and safety systems make use of sensor technology and active warning signs, including flashers, beacons, and dynamic message signs (DMS), to warn drivers of dangerous curves, excessive speed on downhill road segments, at-grade railroad crossings, and other dangerous conditions.

Benefits	
A dynamic truck downhill speed warning system installed on I-70 in Colorado, west of the Eisenhower Tunnel, decreased truck accidents 13% and reduced the use of runaway ramps 24%.[25]	
Costs	
System Cost — A truck speed warning system was deployed on a downgrade curve along I-70 in Glenwood Canyon, Colorado. If a truck is detected (via radar) exceeding the posted speed, then the truck's speed is posted on a DMS. The system cost range is the estimated cost for a single site.[18]	System cost: **$25,000-$30,000** (1996)



Roadway Operations & Maintenance

ITS applications in operations and maintenance focus on integrated management of maintenance fleets, specialized service vehicles, hazardous road conditions remediation, and work zone mobility and safety. These applications monitor, analyze, and disseminate roadway and infrastructure data for operational, maintenance, and managerial uses. ITS can help secure the safety of workers and travelers in a work zone while facilitating traffic flow through and around the construction area. This is often achieved through the temporary deployment of other ITS services, such as elements of traffic management and incident management programs.

Benefits	
Average clearance times for incidents were reduced 44% with the implementation of motorist assistance patrols and a temporary traffic management center during a construction project at the "Big I" interchange in Albuquerque, New Mexico.[26]	
Costs	
System Cost — Michigan DOT teamed up with FHWA and Michigan State University for an 18-month study to test the use of variable speed limits (VSL) in work zones. The equipment, 7 VSL trailers, was rented for the study. The project cost includes the equipment, technical support, and transport of the VSL trailers.[27]	Project cost: **$400,900** (2002)

Road Weather Management

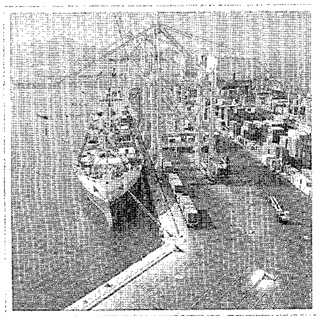
Road weather management activities include road weather information systems (RWIS), winter maintenance technologies, and coordination of operations within and between state DOTs. ITS applications assist with the monitoring and forecasting of roadway and atmospheric conditions, dissemination of weather-related information to travelers, weather-related traffic control measures such as variable speed limits, and both fixed and mobile winter maintenance activities.

Benefits		
An Idaho DOT study found significant speed reductions when weather-related warnings were posted on dynamic message signs. During periods of high winds and snow-covered pavement, vehicle speeds dropped 35% to 35 mph when warning messages were displayed, compared to a 9% drop to 44 mph without the dynamic message signs.[28]		
Costs		
System Cost	Washington State DOT has implemented three highway advisory radios along the Blewett/Stevens Pass to provide weather and road condition information to travelers and maintenance crews.[31]	Average cost of equipment (including installation): **$20,000** (2001) Annual O&M cost: **$1,000** (2001)

Commercial Vehicle Operations

ITS applications for commercial vehicle operations are designed to enhance communication between motor carriers and regulatory agencies. Examples include electronic registration and permitting programs, electronic exchange of inspection data between regulating agencies for better inspection targeting, electronic screening systems, and several applications to assist operators with fleet operations and security.

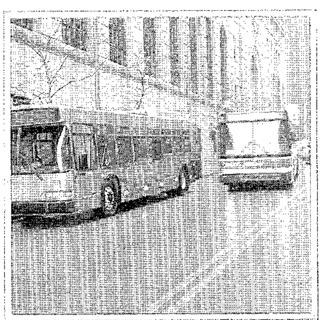
Benefits		
Three motor carriers surveyed during the Commercial Vehicle Information Systems and Network (CVISN) model deployment initiative evaluation indicated that electronic credentialing reduced paperwork and saved them 60-75% on credentialing costs. In addition, motor carriers were able to commission new vehicles 60% faster by printing their own credential paperwork and not waiting for conventional mail delivery.[29]		
Costs		
System Cost	Kentucky and Maryland have implemented end-to-end International Registration Plan (IRP) electronic credentialing systems within their states. The costs to deploy these systems vary with the unique characteristics of each state. A significant impact on cost is whether commercial software is used or special software is developed and if third-party services will be used.[29]	End-to-end IRP cost incurred by the state: **$464,802–$935,906**



Intermodal Freight

ITS can facilitate the safe, efficient, secure, and seamless movement of freight. Applications being deployed provide for tracking of freight and carrier assets such as containers and chassis, and improve the efficiency of freight terminal processes, drayage operations, and international border crossings.

Benefits		
An electronic supply chain manifest system implemented biometric and smart card devices to automate manual, paper-based cargo data transfers between manufacturers, carriers, and airports in Chicago, Illinois, and New York, New York. Although participation was limited, the system was expected to improve efficiency. The time required for truckers to accept cargo from manufacturers decreased by about four minutes per shipment, and the time required for airports to accept the deliveries decreased by about three minutes per shipment.[30]		
Costs		
System Cost	A tracking device installed on fleet trailers can integrate Global Positioning System (GPS) technology with the Internet to provide a secure, cost-effective method for remote and accurate management of trailers. The self-powered unit has a rechargeable battery pack, a roof-mounted combination GPS and wireless antenna, and a roof-mounted solar panel.[31]	Cost: beginning at **$800** per trailer (2000) Monthly service cost: **$19** per subscriber with a 3-year contract (2000)

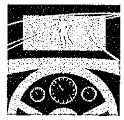


Collision Warning Systems

To improve the ability of drivers to avoid accidents, vehicle-mounted collision warning systems (CWS) continue to be tested and deployed. These applications use a variety of sensors to monitor the vehicle's surroundings and alert the driver of conditions that could lead to a collision. Examples include forward collision warning, obstacle detection systems, and road departure warning systems.

Benefits		
A National Highway Traffic Safety Administration (NHTSA) modeling study indicated collision warning systems would be effective in 42% of rear-end crash situations where the lead vehicle was decelerating, and effective in 75% of rear-end crashes where the lead vehicle was not moving. Overall, collision warning systems would be effective in 51% of crash situations.[32]		
Costs		
System Cost	A Florida-based trucking company has installed a collision warning system to reduce the number of rear-end incidents. Adaptive cruise control can be added to further reduce rear-end collisions.[33,34]	Average cost for CWS with forward-looking and side sensor: **$2,500** Adaptive cruise control: **$350-$400** (extra)

Driver Assistance Systems



Numerous intelligent vehicle technologies exist to assist the driver in operating the vehicle safely. Systems are available to aid with navigation, while others, such as vision enhancement and speed control systems, are intended to facilitate safe driving during adverse conditions. Other systems assist with difficult driving tasks such as transit and commercial vehicle docking.

Benefits		
In-vehicle navigation units were distributed to public agencies in the San Antonio, Texas, area as part of the San Antonio Metropolitan Model Deployment Initiative (MMDI). Focus groups composed of drivers of vehicles equipped with the units indicated that the drivers most satisfied with the system were those who frequently drove different routes each day, particularly paratransit drivers and police investigators. Modeling results indicate significant potential benefits for individuals using the devices. Over a one-year period a traveler using an IVN device could experience an 8.1% reduction in delay, a 4.6% reduction in the crash rate, and a 3% reduction in fuel consumption.[19]		
Costs		
System Cost	The units deployed in San Antonio provided route guidance and real-time traffic conditions. The cost of the units (590 at approximately $2,800 each) was the most significant cost driver for the project. Most of the O&M cost is attributed to database updates.[19]	Capital cost for project: **$2,388,691** (1998) Annual O&M cost: **$102,330** (1998)

Collision Notification Systems

In an effort to improve response times and save lives, collision notification systems have been designed to detect and report the location and severity of incidents to agencies and services responsible for coordinating appropriate emergency response actions. These systems can be activated manually (Mayday), or automatically with automatic collision notification (ACN), and advanced systems may transmit information on the type of crash, number of passengers, and the likelihood of injuries.

Benefits		
Between July 1997 and August 2000, the impacts of advanced ACN on incident notification were tracked for vehicles with and without ACN systems in urban and suburban areas of Erie County, New York. Based on a limited number of crash events, the average notification time for vehicles equipped with ACN was less than one minute with some notification times as long as 2 minutes, and the average notification time for vehicles without ACN was about 3 minutes with some notification times as long as 9, 12, 30, and 46 minutes.[35]		
Costs		
System Cost	Numerous commercial Mayday/ACN products are available as factory-installed and after-market devices. Cost data are more prevalent for after-market devices than for factory-installed systems. Installation costs were not readily available. Annual service fees vary depending on the level of services offered.[36]	After-market device cost range: **$400-$1,895** Monthly service fee: **$10-$27**

1.0 Introduction

Highway travel by Americans continues to grow as population increases, particularly in metropolitan areas. Construction of new highway capacity to accommodate this growth in travel has not kept pace. Between 1980 and 1999, vehicle miles of travel increased 76 percent while road expansion to meet this demand has lagged behind. The Texas Transportation Institute estimates that, in 2000, the 75 largest metropolitan areas experienced 3.6 billion vehicle-hours of delay, resulting in 5.7 billion gallons in wasted fuel and $67.5 billion in lost productivity.[37]

Transit ridership is also on the rise, reaching 9.4 billion trips in 2000, the highest level in 40 years.[38] Freight volumes are forecast to grow by about 69 percent between 1998 and 2020, from 15.3 billion tons, to 25.8 billion tons annually.[39] Largely considered a big-city problem, congestion and related delays are becoming increasingly common in small cities and some rural areas as well. This increasing demand for transportation is causing the transportation system to reach the limits of its existing capacity. Intelligent Transportation Systems (ITS) can help ease this strain through the application of modern information technology and communications.

The goal of ITS is to improve the transportation system to make it more effective, efficient, and safe. Building new transportation infrastructure is expensive and can be detrimental to the environment. In most urban areas where more capacity is needed, it is becoming physically impossible to build enough new roads or new lanes to meet transportation demand. By applying the latest technological advances to our transportation system, ITS can help meet increasing demand for transportation by improving the quality, safety, and effective capacity of our existing infrastructure

ITS represents a wide collection of applications, from advanced traffic signal control systems, to electronic transit fare payment systems, to ramp meters, to collision warning systems. In order to apply ITS services most effectively, it is important to understand their benefits and costs. Some applications provide more cost-effective benefits than others, and as technology evolves, the choices available change. Often, several technologies are combined in a single integrated system, providing a higher level of benefits than any single technology. The costs of these technology investments—not only the first-time, initial costs, but the costs to operate and maintain them—are of interest to transportation agencies.

New in the 2003 report is the inclusion of cost information for representative ITS deployments.

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1.0 Introduction

This report presents an assessment of the effect of ITS applications on several important impact areas. These assessments are built from findings in the benefits portion of the database, incorporating additions since the completion of the last report. While the assessments are based on the authors' review of all study findings, the highlighted examples are only a portion of the total number of studies documented in the ITS Benefits Database. The impact assessments for each ITS application area are presented through a rating system, as shown in **Table 1.0.1**. These ratings were developed through individual review of the database content by the authors, with additional discussion among the authors to establish the final ratings presented in this report. A particular rating was assigned if one or more of the reasons in the rationale column in **Table 1.0.1** was evident in reviewing the evaluations of a given ITS application in the Benefits Database.

Table 1.0.1
Definition of Impact Ratings for Assessment of ITS Applications

Symbol	Impact Rating	Rationale
++	substantial positive impacts	• several studies with positive findings • documented impact of relatively large magnitude
+	positive impacts	• several studies documenting positive findings though the impact may be small or moderate • single, relatively rigorous study documented a positive impact
O	negligible impact	• studies performed found little significant impact
+/-	mixed results	• studies have found both positive and negative impacts on a given measure
?	not enough data	• usually, only a single study is available, and results cannot be taken to indicate a trend • studies in database have limited sample sizes, or study durations • studies in database are from a single location, and impacts are expected to vary in different locations
-	negative impacts	• several studies documenting negative findings • single, relatively rigorous study documenting a negative impact

The majority of published evaluations of ITS implementations document positive impacts on the transportation system, and the assessments provided in this report reflect this fact. However, every attempt has been made to incorporate positive, negative, and neutral findings. A small number of negative findings appear in this report: for example, Section 2.6 documents increases in crashes at toll plazas with electronic toll collection, likely due to driver uncertainty regarding plaza configuration and the variations in the speeds of vehicles within the plazas. This report also documents a few evaluations which found that an ITS implementation did not have an impact on a particular measure of effectiveness, including two studies that found traveler information did not have a significant impact on capacity, while it did reduce traveler delay. Mixed results are also noted in the few instances where studies have found both positive and negative impacts in a given area. There is a continuing need for ongoing evaluation of ITS, as indicated by the large number of application areas within this report for which there are not enough evaluation data to make an assessment of the system's impact on many of the relevant performance measures.

An interactive version of this report will be available through the database website in the near future.

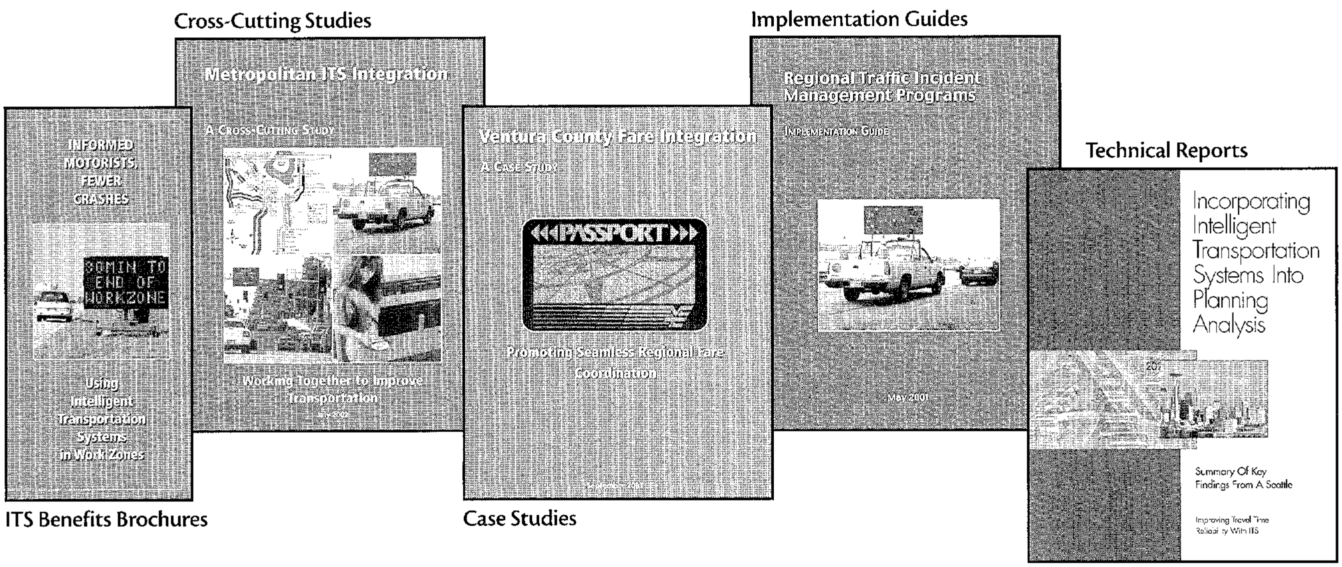
Interested readers are encouraged to check the database from time to time for the latest findings on the benefits and costs of ITS. This report is intended to be a reference report; it highlights impacts and system cost data identified by other authors. The interested reader is encouraged to obtain source documents to appreciate the assumptions and constraints placed upon interpretation of results. An interactive version of this report will be available through the database website in the near future, including links from sections of the report to relevant portions of the ITS Benefits and Unit Costs Database. The database includes more detailed summaries of the evaluations cited in this report as well as links to source documents, when available online.

While this report focuses on documenting and assessing the impacts of ITS implementations on the transportation system as well as the costs of these implementations, the ITS JPO has also published a number of other documents to convey lessons learned in the implementation of ITS. The report, *What Have We Learned About Intelligent Transportation Systems?*, published in 2000, contains a more comprehensive examination of which ITS technologies have been successful over the 10-year history of the National ITS Program, which ITS technologies have not been successful, and what are the underlying factors that determine success or failure.[41]

The ITS JPO's website is another valuable resource for information on the various applications of ITS. The website, **www.its.dot.gov**, also includes links to many of the resources highlighted within this report, including an electronic document library, which contains electronic copies of many of the reports made available by the JPO.

In addition, for those ITS technologies with a well-established track record, the U.S. DOT has developed a series of reports that help decision-makers learn about how those ITS solutions can address local and regional transportation needs. There are several different types of reports in the series, each designed to communicate with target audiences at various levels:

- **ITS Benefits Brochures** let experienced community leaders and transportation professionals explain in their own words how specific ITS technologies have benefited their areas.
- **Cross-Cutting Studies** examine various ITS approaches that can be taken to meet a community's goals.
- **Case Studies** provide in-depth coverage of specific approaches taken by communities across the U.S.
- **Implementation Guides** serve as "how to" manuals to assist project staff in the technical details of implementing ITS.
- **Technical Reports** are easy-to-read excerpts from more detailed evaluation reports.



In addition to lessons learned and other reports developed to assist transportation decision-makers, information is available on how much and what types of ITS deployment have taken place. The ITS Metropolitan Deployment Tracking project began in 1996 with the goal of tracking the level of ITS deployment and integration in 75 of the nation's largest metropolitan areas. The number of metropolitan areas was later increased to 78. In 1997, and again in 1999 and 2000, data were collected based on a series of surveys targeted at 78 of the largest metropolitan areas. Beginning in 2002, the target areas were expanded to include 30 medium-sized, high-congestion areas, 20 tourist areas, and 50 statewide/rural areas. Results of the data collected for 2002 will be available at the ITS Deployment Tracking web site, **www.itsdeployment.its.dot.gov**, in early summer 2003.

1.1 Benefits Database Goals and Overview

To expand the understanding of ITS benefits, the U.S. DOT's ITS JPO has been actively collecting information regarding the impact of ITS implementations over the past decade. In support of this effort, the JPO sponsored the development of the ITS Benefits Database. The database is available to the public at **www.benefitcost.its.dot.gov**. The database contains the most recent data collected by the JPO. Its purpose is to transmit existing knowledge of ITS benefits to the transportation professionals. The database also provides the research community with information on ITS areas where further analysis may be required.

The Benefits Database website contains detailed summaries of each of the ITS evaluation reports reviewed by the JPO that met the acceptance criteria. Summaries on the web pages provide additional background on the context of the evaluations, the evaluation methodologies used, and links to the source documentation (when available online). While the JPO publishes reports such as this periodically, the online database is updated quarterly to reflect the most recent reports reviewed. Documents reviewed for inclusion in the database include the results of federal evaluation projects, as well as papers, journal articles, and state or local evaluation reports identified through review of conference proceedings and journals, or through e-mail submission via the website. The collection of evaluation reports is an ongoing program, and readers are encouraged to submit relevant documents via the database website.

The online database also provides several capabilities to simplify access to information relevant to a researcher's interest. In addition to using the classification system in this report, interested researchers can access document summaries classified by project location and ITS goal areas addressed in the evaluations, or search the database for relevant keywords. These capabilities of the online database simplify access to the most recently available data on ITS benefits identified by the JPO. The website also contains a discussion of the criteria and sources used to determine whether or not a report should be added to the ITS Benefits Database.

1.2 Unit Costs Database Goals and Overview

The ITS JPO also collects information on ITS costs, and maintains this information in the ITS Unit Costs Database. The database, a companion to the Benefits Database, is available to the public at the same website, **www.benefitcost.its.dot.gov** (and also presented in Appendix A). The database is a central site for ITS cost data and is based on the most recent data collected by the JPO. Its purpose is to make cost data available to public and private organizations. The database also provides data that the ITS JPO can use for programmatic and policy decisions, and education of ITS stakeholders.

The ITS Unit Costs Database consists of a range of reported costs for a set of ITS elements. The cost data are organized by "subsystem" and generally follow the structure of the National ITS Architecture. The cost estimates are categorized as capital and operating and maintenance (O&M) costs. Capital costs are the costs expended for one-time, non-recurring purchases. Operations and maintenance costs, often referred to as recurring costs, are the annual costs incurred on an ongoing basis. Costs are presented in a range to capture the lows and highs of the cost elements from the different data sources. A "Notes" field provides a brief narrative describing the particular unit cost element and its components. The cost data are useful in developing project cost estimates during the planning process. However, the user is encouraged to find local/regional data sources and current vendor data in order to perform a more detailed cost estimate.

Currently, example system costs from deployments are not contained in the Unit Costs Database or on the website. The collection of cost data is an ongoing program, and readers are encouraged to submit relevant cost data (and benefits data) via the database website. As new cost data become available, existing costs for the unit cost elements will be revised and new unit cost elements will be added.

1.3 A Few Good Measures

In the spring of 1996, the ITS JPO established a set of ITS program goal areas directly related to the ITS strategic plan.[42] The goal areas include improving traveler safety, improving traveler mobility, improving system efficiency, increasing the productivity of transportation providers, and conserving energy while protecting the environment. The JPO also identified several measures of effectiveness to evaluate the performance of ITS services in each goal area. The measures are known as the "Few Good Measures" and are intended to enable project managers to gauge the effects and impacts of ITS. The following is an overview of the various measures of effectiveness within each goal area.

Safety

An explicit objective of the transportation system is to provide a safe environment for travel while continuing to strive to improve the performance of the system. Although undesirable, crashes and fatalities are an inevitable occurrence. Several ITS services aim to minimize the risk of crash occurrence. This goal area focuses on reducing the number of crashes, and lessening the probability of a fatality should a crash occur. Typical measures of effectiveness used to quantify safety performance include the overall crash rate, fatality crash rate, and injury crash rate. Surrogate measures are also used, including vehicle speeds, speed variability, or changes in the number of violations of traffic safety laws.

Mobility

Improving mobility by reducing delay and travel time is a major goal of many ITS components. Measures of effectiveness typically used to evaluate mobility include the amount of delay time and the variability in travel time.

Delay can be measured in many different ways depending on the type of transportation system being analyzed. Delay of a system is typically measured in seconds or minutes of delay per vehicle. Also, delay for users of the system may be measured in person-hours. Delay for freight shipments could be measured in time past scheduled arrival time of the shipment. Delay can also be measured by observing the number of stops experienced by drivers before and after a project is deployed or implemented.

Travel time variability indicates the variability in overall travel time from an origin to a destination in the system, including any modal transfers or en-route stops. This measure of effectiveness can be readily applied to intermodal freight (goods) movement as well as personal travel. Reducing the variability of travel time improves the reliability of arrival time estimates that travelers or companies use to make planning and scheduling decisions. By improving operations, improving incident response, and providing information on delays, ITS services can reduce the variability of travel time in transportation networks. For example, traveler information products can be used in trip planning to help re-route commercial drivers around congested areas resulting in less variability in travel time.

Capacity/Throughput

Many ITS components seek to optimize the efficiency of existing facilities and use of rights-of-way so that mobility and commerce needs can be met while reducing the need to construct or expand facilities. This is accomplished by increasing the effective capacity of the transportation system. Effective capacity is the "maximum potential rate at which persons or vehicles may traverse a link, node, or network under a representative composite of roadway conditions," including "weather, incidents, and variation in traffic demand patterns."[43] Capacity, as defined by the *Highway Capacity Manual*, is the "maximum hourly rate at which persons or vehicles can reasonably be expected to traverse a given point or uniform section of a lane or roadway during a given time period under prevailing roadway, traffic, and control conditions."[44] The major difference between effective capacity and capacity is that capacity is generally measured under typical conditions for the facility, such as good weather and pavement conditions, with no incidents affecting the system, while effective capacity can vary depending upon these conditions and the use of management and operational strategies. Throughput is defined as the number of persons, goods, or vehicles traversing a roadway section or network per unit time. Increases in throughput are sometimes realizations of increases in effective capacity. Under certain conditions, it may reflect the maximum number of travelers that can be accommodated by a transportation system. Throughput is more easily measured than effective capacity and therefore can be used as a surrogate measure when analyzing the performance of an ITS project.

Customer Satisfaction

Given that many ITS projects and programs were specifically developed to serve the public, it is important to ensure that traveler expectations are being met or surpassed. Customer satisfaction measures characterize the difference between users' expectations and experiences in relation to a service or product. The central question in a customer satisfaction evaluation is, "Does the product deliver sufficient value (or benefits) in exchange for the customer's investment, whether the investment is measured in money or time?" Typical results reported in evaluating the impacts of customer satisfaction with a product or service include product awareness, expectations of product benefit(s), product use, response (decision-making or behavior change), realization of benefits, and assessment of value. Although satisfaction is difficult to measure directly, measures related to satisfaction can be observed, including amount of travel in various modes, mode choices, and the quality of service as well as the volume of complaints and/or compliments received by the service provider.

In addition to user or customer satisfaction, it is necessary to evaluate the satisfaction of the transportation system provider or manager. For example, many ITS projects are implemented to better coordinate between various stakeholders in the transportation arena. In such projects, it is important to measure the satisfaction of the transportation provider to ensure the best use of limited funding. One way to measure the performance of such a project is to survey transportation providers before and after a project has been implemented to see if coordination was improved. It may also be possible to bring together providers from each of the stakeholder groups to evaluate their satisfaction with the system before and after the implementation of an ITS project.

Productivity

ITS implementations can reduce operating costs and allow productivity improvements. Some applications may save time in completing business or regulatory processes, enabling businesses to increase their economic efficiency. For public agencies, ITS alternatives for transportation improvements may have lower acquisition costs and life cycle costs when compared to traditional transportation improvements. Other ITS applications enable the collection and synthesis of data that can translate into cost savings and performance improvements. Operational efficiencies and cost savings made possible by ITS implementation can help both public and private entities make the most productive use of their resources. The measure of effectiveness for this goal area is cost savings as a result of implementing ITS.

Energy and Environment

The air quality and energy impacts of ITS services are very important considerations, particularly for non-attainment areas. In most cases, environmental benefits can only be estimated by the use of analysis and simulation. The problems related to regional measurement include the small impact of individual projects and large numbers of exogenous variables including weather, contributions from non-mobile sources, air pollution drifting into an area from other regions, as well as the time-evolving nature of ozone pollution. Small-scale studies generally show positive impacts on the environment. These impacts result from smoother and more efficient flows in the transportation system. However, environmental impacts of travelers reacting to large-scale deployment in the long term are not well understood.

Decreases in emission levels and energy consumption have been identified as measures of effectiveness for this goal area. Specific measures of effectiveness for emission levels and fuel use include:

- Emission levels (kilograms or tons of pollutants including carbon monoxide (CO), oxides of nitrogen (NOx), hydrocarbons (HC), and volatile organic compounds)
- Fuel use (liters or gallons)
- Fuel economy (km/L or miles/gal)

1.4 Report Organization

This report follows a taxonomy for reporting ITS benefits and costs data. The ITS taxonomy used in this report groups benefits and costs data into two major components: Intelligent Infrastructure and Intelligent Vehicles. These components are then divided into program areas and specific ITS application areas. **Figures 1.4.1** through **1.4.3** present an overview of this taxonomy. Subsequent sections of this report provide additional detail within each segment of the taxonomy.

Intelligent Transportation Systems

- Intelligent Infrastructure
- Intelligent Vehicles

Figure 1.4.1
Taxonomy for ITS

The taxonomy cannot represent all aspects of ITS. For example, many of the program areas can be dependent on or heavily influenced by other areas. This dependency is not well shown in the taxonomy. Also note that many ITS program areas share information and operate in a cooperative manner which is difficult to capture in this format. For example, traveler information systems, especially those regional or multimodal in nature, must rely on surveillance data collected by other ITS applications such as freeway, arterial, and transit management systems. In addition, in-vehicle driver assistance systems, such as navigation, can be augmented by a cooperative infrastructure to provide routing and/or travel time information to vehicle systems. Within this report, in cases of integrated deployment of more than one application, system cost and impact data appear under the program area that the implementation most directly supports.

Sections 2 and 3 begin with a brief description of the ITS taxonomy components, Intelligent Infrastructure and Intelligent Vehicles, respectively. Subsequent subsections within these two sections include a brief description of each program area and specific ITS application area. The benefits and costs data are presented in tabular format based on the taxonomy structure for each program area. Within these tables, impact information is presented by goal area (e.g., safety, mobility, etc.) followed by a listing of relevant unit cost elements (refer to Appendix A) and concluding with available examples of system cost data.

Figure 1.4.4 is an excerpt of **Table 2.1.1** discussing the benefits and costs of arterial management systems; this portion presents the benefits and costs of adaptive signal control. Several pieces of information are provided in the benefits portion of the data table in each section of this report. The "Goal Area," one of the "Few Good Measures" discussed earlier in Section 1.3, is followed by the "Number of Studies" in the database identifying impacts within that goal area for a given application of ITS. The "Impact" rating in the third column represents an assessment of the application's impact on the performance goal area, considering the collection of reports in the

Intelligent Infrastructure

Program Areas

- Arterial Management Systems
- Freeway Management Systems
- Transit Management Systems
- Incident Management Systems
- Emergency Management Systems
- Electronic Payment Systems
- Traveler Information
- Information Management
- Crash Prevention & Safety
- Roadway Operations & Maintenance
- Road Weather Management
- Commercial Vehicle Operations
- Intermodal Freight

Figure 1.4.2
Taxonomy for the Intelligent Infrastructure

Intelligent Vehicles

Program Areas

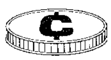
- Collision Warning Systems
- Driver Assistance Systems
- Collision Notification Systems

Figure 1.4.3
Taxonomy for Intelligent Vehicles

1.4 Report Organization

Impact Legend
- ++ substantial positive impacts
- + positive impacts
- ⊃ negligible impact
- +/– mixed results
- ? not enough data
- – negative impacts

database (a more complete discussion is provided in **Table 1.0.1**). Impact ratings fall into one of the six categories defined in the **Impact Legend** to the left, which is also repeated in each subsection within Sections 2 and 3 of this report. Example impacts for each application are included in the final column of the table, drawn from representative studies within the database.


The costs portion of the data tables in each section includes a listing of relevant unit cost subsystems for the application. The icon **to the left** identifies applicable subsystems in the ITS Unit Costs Database for the given application area, which can be used to refer to unit cost information in Appendix A. The Unit Costs Database is regularly updated, with the most recent data available at **www.benefitcost.its.dot.gov**.


Sample system cost information, along with a brief description of the implemented system, follows the unit cost information in each data table and is identified by the icon **to the left**. The purpose of presenting system cost information is to give the reader an example of systems that have been deployed along with the costs of each particular implementation. The reader is reminded that the costs represented are taken from the source documents and have not been adjusted to reflect 2003 dollars. The parenthetical date following the system cost information represents the year the cost data are based on, when known.

A summary of the data presented in this report is provided in Section 4. A list of references and endnotes follows Section 4. Appendix A contains the ITS Unit Costs Database in table format, as of 30 September 2002. Appendix B contains a listing of acronyms used throughout the report.

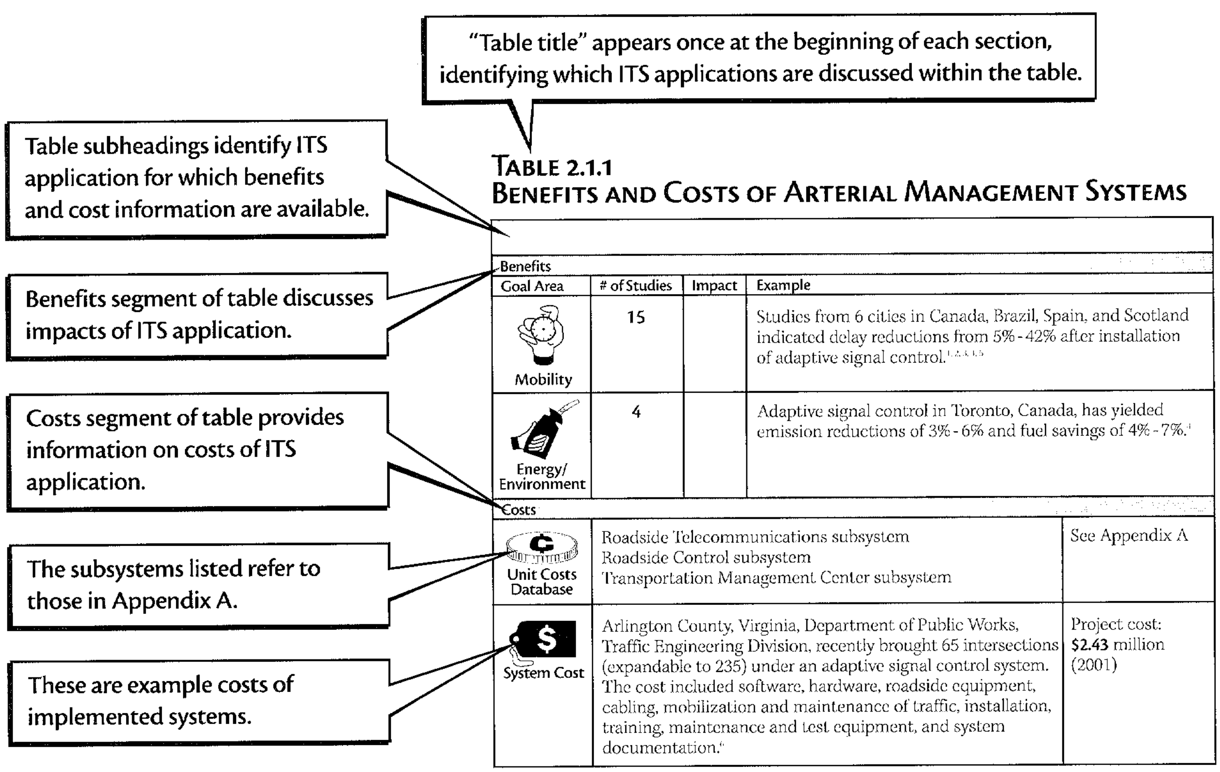
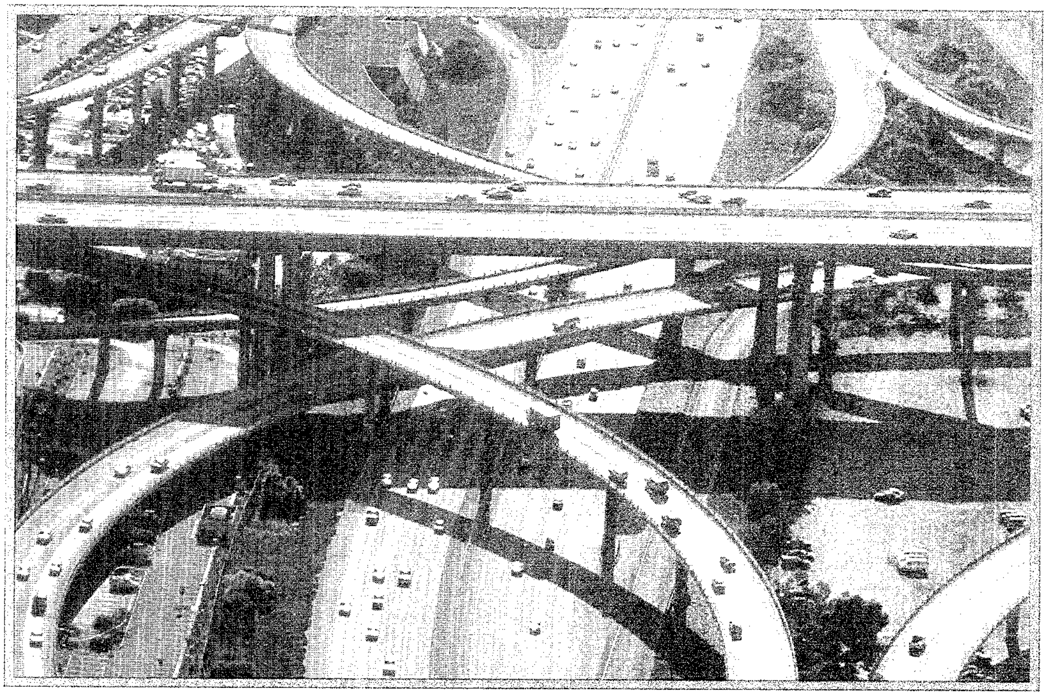


Figure 1.4.4
Excerpt of Table 2.1.1 (describing the benefits and costs of Adaptive Signal Control)

2.0 Benefits and Costs of the Intelligent Infrastructure



The Intelligent Infrastructure consists of a wide variety of applications intended to improve the safety and mobility of the traveling public, while enabling organizations responsible for providing transportation facilities and services to do so more efficiently. Sections 2.1 to 2.13 of this report will discuss specific applications within the 13 program areas that make up the Intelligent Infrastructure listed in **Figure 2.0**. ITS can be deployed to improve the operation of freeways, arterials, and transit systems. Several applications can support critical transportation functions during emergency situations. Other applications facilitate convenient payment for highway tolls and transit fares. Traveler information programs synthesize information collected by ITS and disseminate it to travelers for their benefit in making travel decisions. Information management programs help transportation organizations manage and analyze the flow of data from deployed ITS and use it to improve transportation operations. Crash prevention and safety applications provide a variety of countermeasures, often location-specific, to address transportation safety concerns. Road weather management implementations improve the ability of the highway transportation system to react to adverse weather conditions. Several applications can

INTELLIGENT INFRASTRUCTURE

Program Areas

- Arterial Management Systems
- Freeway Management Systems
- Transit Management Systems
- Incident Management Systems
- Emergency Management Systems
- Electronic Payment Systems
- Traveler Information
- Information Management
- Crash Prevention & Safety
- Roadway Operations & Maintenance
- Road Weather Management
- Commercial Vehicle Operations
- Intermodal Freight

Figure 2.0
Taxonomy for the Intelligent Infrastructure

improve the daily operation and continuing maintenance of the highway system. ITS for commercial vehicle operations (ITS/CVO) and intermodal freight applications help facilitate the smooth and safe flow of freight throughout the country and at our borders.

Several metropolitan areas are implementing ITS services that are very highly integrated. Integration is accomplished by creating a number of interfaces or "links" between components, systems, services, or program areas. These links are used to share operational information and allow better use of infrastructure across jurisdictional boundaries. One example is sharing arterial traffic condition information originating from a traffic signal system with a freeway management system, allowing the freeway management system to provide expected travel times on alternate routes during congested periods. There are numerous other ways of integrating various implementations of ITS to achieve benefits greater than those of the individual system. The online Benefits Database contains a section presenting the evaluation reports that discuss integrated systems.

For a more complete understanding of the integration of ITS components, consult the following documents:

- *Metropolitan ITS Integration: A Cross-Cutting Study*. FHWA Report (FHWA-OP-02-083), FTA Report (FTA-TRI-11-02-05). Electronic Document Number 13672.
- *Tracking the Deployment of Integrated Metropolitan Intelligent Transportation Systems Infrastructure in the USA: FY99 Results*. FHWA Report (FHWA-OP-00-016). March 2000. Electronic Document Number 13159.
- "Measuring ITS Deployment and Integration." Prepared for the FHWA ITS JPO. January 1999. Electronic Document Number 4372.

These documents are electronically available on the FHWA electronic document library at **www.its.dot.gov/itsweb/welcome.htm**. The JPO-sponsored deployment tracking website, **itsdeployment.ed.ornl.gov**, contains updated information on ITS deployment in the United States.

2.1 Arterial Management Systems

Arterial management systems manage traffic along arterial roadways, employing traffic detectors, traffic signals, and various means of communicating information to travelers. These systems make use of information collected by traffic surveillance devices to smooth the flow of traffic along travel corridors. They also disseminate important information about travel conditions to travelers via technologies such as dynamic message signs (DMS) or highway advisory radio (HAR).

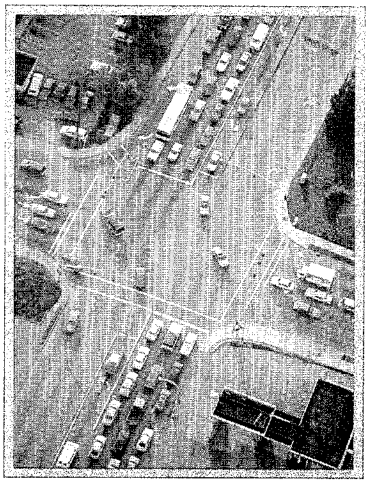
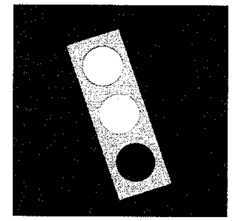


Figure 2.1.1, showing a portion of the ITS taxonomy, lists the variety of systems that may be employed as part of arterial management systems. Many of the services possible through arterial management systems are enabled by traffic surveillance technologies, such as sensors or cameras monitoring traffic flow.

Traffic signal control systems address a number of objectives, primarily improving traffic flow and safety. Transit signal priority systems can ease the travel of buses or light-rail vehicles traveling arterial corridors and improve on-time performance. Signal preemption for emergency vehicles enhances the safety of emergency responders, reducing the likelihood of crashes while improving response times. Adaptive signal control systems coordinate control of traffic signals across metropolitan areas, adjusting the lengths of signal phases based on prevailing traffic conditions. Advanced signal systems include coordinated signal operations across neighboring jurisdictions, as well as centralized control of traffic signals which may include some necessary technologies for the later development of adaptive signal control. Pedestrian detectors, specialized signal heads, and bicycle-actuated signals can improve the safety of all road users at signalized intersections. Arterial management systems with unique operating schemes can also smooth traffic flow during special events.

A variety of techniques are available to manage the travel lanes available on arterial roadways, and ITS applications can support many of these strategies. Examples include dynamic posting of high-occupancy vehicle (HOV) restrictions and the use of reversible flow lanes allowing more lanes of travel in the peak direction of travel during rush hours. Parking management systems, most commonly deployed in urban centers or at modal transfer points such as airports, monitor the availability of parking and disseminate the information to drivers, reducing traveler frustration and congestion associated with searching for parking. Organizations operating ITS can share information collected by detectors associated with arterial management systems with road users through technologies within the arterial network, such as

INTELLIGENT INFRASTRUCTURE



ARTERIAL MANAGEMENT SYSTEMS

- **Traffic Surveillance**
- **Traffic Control**
  - Transit Signal Priority
  - Emergency Vehicle Preemption
  - Adaptive Signal Control
  - Advanced Signal Systems
  - Variable Speed Limits
  - Bicycle & Pedestrian
  - Special Events
- **Lane Management**
  - HOV Facilities
  - Reversible Flow Lanes
  - Pricing
  - Lane Control
  - Variable Speed Limits
  - Emergency Evacuation
- **Parking Management**
- **Information Dissemination**
  - Dynamic Message Signs (DMS)
  - In-Vehicle Systems (IVS)
  - Highway Advisory Radio (HAR)
- **Enforcement**
  - Speed Enforcement
  - Stop/Yield Enforcement

Figure 2.1.1
Taxonomy for Arterial Management Systems

dynamic message signs or highway advisory radio. Arterial management systems may also include automated enforcement programs that increase compliance with speed limits, traffic signals, or other traffic control devices.

Sharing information with other components of the ITS infrastructure can also have a positive impact on the operation of the transportation system. Examples include coordinating operations with a freeway management system, or providing arterial information to a traveler information system covering multiple roadway and public transit facilities.

For a summary of arterial management systems deployments across the U.S., refer to **www.itsdeployment.its.dot.gov**.

Table 2.1.1 provides information on the benefits and costs of arterial management systems. Information provided on the impacts of these systems is indicated by using the symbols in the Impact Legend at the bottom corner of each page.

Table 2.1.1
Benefits and Costs of Arterial Management Systems

Traffic Surveillance		
Benefits		
Supporting role, no benefits information.		
Costs		
Unit Costs Database	Roadside Telecommunication subsystem Roadside Detection subsystem Transportation Management Center subsystem	See Appendix A
System Cost	Washington State DOT's Northwest Region installed cameras at two intersections in the town of Kenmore. The main purpose for installing the cameras is to improve signal operations on arterials. In addition, WSDOT engineers can observe traffic conditions and detect incidents. The total cost includes five cameras, telecommunication/video equipment, and labor.[45]	Project cost: **$65,000** (2002)

Impact Legend
- ++ substantial positive impacts
- \+ positive impacts
- o negligible impact
- +/– mixed results
- ? not enough data
- – negative impacts

Traffic Control: Transit Signal Priority

Benefits

Goal Area	# of Studies	Impact	Example
Mobility	13	++	Experience in 10 cities in the U.S. and abroad show -2% to 20% improvement in bus travel time.[46, 47, 48, 50, 51] Several studies show significant reduction in travel time variability, with a corresponding improvement in on-time performance.
Productivity	1	+	On a Toronto, Canada light-rail transit line, signal priority allowed same level-of-service with less rolling stock.[52]
Energy/ Environment	1	+	Simulation of a priority system implemented on a Helsinki, Finland, bus line indicated reductions of HC, CO, and NOx, as well as a 3.6% reduction in fuel consumption.[49]

Costs

Unit Costs Database	Roadside Telecommunications subsystem Roadside Control subsystem Transit Management Center subsystem Transit Vehicle On-board subsystem Transportation Management Center subsystem	See Appendix A
System Cost	A state grant was used to purchase signal priority transmitters for approximately 27 buses and receivers for 10 traffic lights in Chattanooga, Tennessee.[53]	Cost: **$250,000** (2001)
System Cost	The city of Los Angeles, California, in collaboration with the LA County Metropolitan Transportation Authority (MTA), implemented a transit priority system for buses along two major transit corridors. Initial deployment began in June 2000. The project consisted of 331 loop transponders at 210 intersections, 150 transponder equipped buses, and central control software. The cost per signalized intersection included the average roadway equipment, intersection and software costs.[54]	Average cost: **$13,500** per signalized intersection (2000) Transponder cost: Approximately **$75** per bus (2000)
System Cost	The cost of transit signal priority systems varies based on many factors such as system design and functionality, and type of equipment. Based on information reported in a recent ITS America report, the per intersection cost of a transit priority system covers a wide range.[55]	Cost range: **$8,000-$35,000** per intersection

The Los Angeles DOT (LADOT) implemented a $10 million bus signal priority demonstration project along two corridors (Ventura Boulevard and the Santa Monica-Beverly Hills-Montebello route) in the City of Los Angeles, California. The initial deployment began in June 2000. The system consists of 331 loop detectors, 210 intersections equipped with AVI sensors at the controller cabinet, and 150 transponder-equipped buses. Loop detection technology is used to detect the presence of a bus approaching the intersection. The bus identification is detected by the AVI sensor and sent to the transit management computer located at the LADOT transportation management center. The system checks the bus' schedule and headway to determine if it is early or on time. If the bus is behind schedule, one of four types of priority modes is granted. Loop detection was selected as the most reliable, accurate, and cost-effective detection technology, over radio-frequency antenna-transponder detection and infrared beacon system.[50, 56] (2000)

Impact Legend

- ++ substantial positive impacts
- + positive impacts
- ○ negligible impact
- +/– mixed results
- ? not enough data
- – negative impacts

Traffic Control: Emergency Vehicle Preemption

Benefits		
No data to report.		
Costs		
Unit Costs Database	Roadside Telecommunications subsystem Roadside Control subsystem Emergency Response Center subsystem Emergency Vehicle On-board subsystem Transportation Management Center subsystem	See Appendix A
System Cost	Several intersections in British Columbia, Canada, were equipped for emergency vehicle preemption. The siren of an emergency vehicle is detected and initiates a green signal for the oncoming vehicle. Pedestrian crossing signals are switched to "Don't Walk." A visual verification system (set of blue-and-white lights) indicates that the intersection is controlled by an emergency vehicle preemption system and when the system has been activated.[18]	Cost: **$4,000** per intersection (can be less if multiple intersections are equipped)

Traffic Control: Adaptive Signal Control

Goal Area	# of Studies	Impact	Example
Benefits			
Mobility	15	++	Studies from 6 cities in Canada, Brazil, Spain, and Scotland indicated delay reductions from 5% - 42% after installation of adaptive signal control.[1,2,3,4,5]
Energy/ Environment	4	+	Adaptive signal control in Toronto, Canada, has yielded emission reductions of 3% - 6% and fuel savings of 4% - 7%.[4]

Costs		
Unit Costs Database	Roadside Telecommunications subsystem Roadside Control subsystem Transportation Management Center subsystem	See Appendix A
System Cost	Arlington County, Virginia, Department of Public Works, Traffic Engineering Division, recently brought 65 intersections (expandable to 235) under an adaptive signal control system. The cost included software, hardware, roadside equipment, cabling, mobilization and maintenance of traffic, installation, training, maintenance and test equipment, and system documentation.[6]	Project cost: **$2.43** million (2001)

Impact Legend
- ++ substantial positive impacts
- \+ positive impacts
- o negligible impact
- +/- mixed results
- ? not enough data
- – negative impacts

Traffic Control: Advanced Signal Systems

Benefits

Goal Area	# of Studies	Impact	Example
Safety	2	+	Signal coordination along a Phoenix, Arizona, corridor resulted in a 6.7% reduction in crash risk, calculated based on improved travel speeds and a reduction in the average number of stops.[57]
Mobility	12	++	Implementation of signal coordination along 76 corridors in California cities reduced vehicle delay when traveling the corridors by 25%.[58]
Productivity	3	+	Assigning a monetary value to reductions in delay, fuel use, and emissions achieved during a $4.7 million dollar upgrade of the Richmond, Virginia, signal system yielded benefits of $4.2 million annually.[59]
Energy/ Environment	6	+	Modeling results after the implementation of coordinated signal control in four U.S. localities found reductions in fuel use ranging from a 2% savings in Phoenix, Arizona, to a 12% decline in Richmond, Virginia.[57,60]

Costs

Unit Costs Database	Roadside Telecommunications subsystem Roadside Control subsystem Transportation Management Center subsystem	See Appendix A
System Cost	The North Seattle Advanced Traffic Management System (ATMS) was enhanced to allow the integration of 19 metropolitan North Seattle, Washington, city signal systems. The enhancement also included interconnection with the Traffic Control Centers (TCCs) of nine cities, three transit agencies, and Washington State DOT's arterial signal and freeway ramp metering systems as well as the East and South Seattle ATMSs. The ATMS also collects regional traffic data.[20]	Capital cost: **$1.7** million (**$200K** for detection devices) (1998) O&M cost: **$140,000** (1998)
System Cost	The city of Indianapolis, Indiana, upgraded 220 intersections in downtown and connected the intersections to a central computer system. The upgrade involved synchronizing the traffic signals along the city's busiest intersections.[61]	Cost: **$5.1** million

Impact Legend

- ++ substantial positive impacts
- \+ positive impacts
- ○ negligible impact
- +/– mixed results
- ? not enough data
- – negative impacts

Traffic Control: Bicycle & Pedestrian		
Benefits		
No data to report.		
Costs		
Unit Costs Database	Roadside Telecommunications subsystem Roadside Detection subsystem Roadside Information subsystem	See Appendix A
System Cost	A downtown Boulder, Colorado, intersection has been equipped with a series of four flashing in-pavement lights per lane. This high pedestrian-volume intersection is also equipped with two flashing pedestrian signs. The lights and signs are activated manually. Project cost includes equipment and installation costs.[18]	Project cost: **$8,000-$16,000**

Parking Management			
Benefits			
Goal Area	**# of Studies**	**Impact**	**Example**
Capacity/ Throughput	1	?	Experience with parking management systems in Europe indicate a 25% reduction in downtown traffic volumes related to the search for parking.[62]

Costs		
Unit Costs Database	Roadside Telecommunications subsystem Parking Management subsystem	See Appendix A
System Cost	A real-time parking availability information system for ten parking facilities was implemented in the downtown St. Paul, Minnesota, area. The initial cost included system design and development, management and coordination, and equipment and installation.[63]	Capital cost: **$992,000** (1995) O&M cost: **$36,350** (1995)

Impact Legend
- ++ substantial positive impacts
- \+ positive impacts
- o negligible impact
- +/– mixed results
- ? not enough data
- – negative impacts

Information Dissemination: Dynamic Message Signs

Benefits		
No data to report (for applications on arterials).		
Costs		
Unit Costs Database	Roadside Telecommunications subsystem Roadside Information subsystem Transportation Management Center subsystem	See Appendix A
System Cost	No data to report (for applications on arterials)	

Information Dissemination: In-Vehicle Systems (IVS)

Benefits		
No data to report.		
Costs		
Unit Costs Database	Vehicle On-Board subsystem	See Appendix A
System Cost	No data to report.	

Enforcement: Speed Enforcement

Benefits

Goal Area	# of Studies	Impact	Example
Safety	4	+	An Institute of Transportation Engineers (ITE) synthesis study on automated enforcement lists two U.S. cities with automated speed limit enforcement programs, with documented crash reductions of 40% in Paradise Valley, Arizona, and 51% in National City, California.[64]

Costs

Unit Costs Database	Roadside Telecommunications subsystem Roadside Detection subsystem Roadside Information subsystem	See Appendix A
System Cost	A one-year pilot for automated speed enforcement was implemented in Denmark. The pilot program involved nine vehicle-mounted cameras.[65]	Cost: **5.9** million euros (approx. **$5.9** million United States Dollars [USD])

Impact Legend
- ++ substantial positive impacts
- + positive impacts
- ○ negligible impact
- +/– mixed results
- ? not enough data
- – negative impacts

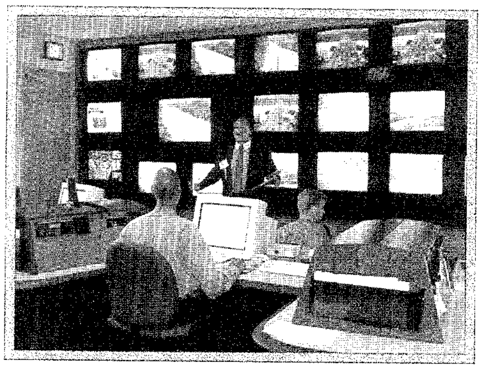
Enforcement: Stop/Yield Enforcement

Goal Area	# of Studies	Impact	Example
Benefits			
Safety	11	?	Red light camera programs have resulted in reported violation reductions ranging from 20 - 87%, inconclusive findings on crash impacts.[66]
Customer Satisfaction	2	++	Public opinion surveys indicated 60 - 80% support for red light camera programs.[66]
Costs			
Unit Costs Database	Roadside Telecommunications subsystem Roadside Detection subsystem		See Appendix A
System Cost	Red light enforcement cameras have been implemented in numerous cities throughout the U.S. The cost of equipping an intersection for red light enforcement depends on the geometry of the intersection and the number of lanes monitored. Typical implementation costs include camera, poles, loops, wires, and installation. The cost range represents the costs incurred per intersection for the city of Jackson, Michigan, (low-end) and the City of San Francisco, California, (high-end).[67]		Costs per intersection: **$67,000-$80,000**

Impact Legend
- ++ substantial positive impacts
- \+ positive impacts
- ○ negligible impact
- +/– mixed results
- ? not enough data
- – negative impacts

2.2 Freeway Management Systems

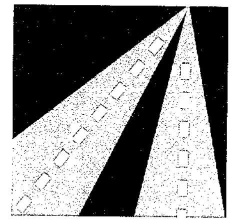
There are six major ITS functions that make up freeway management systems, as shown in **Figure 2.2.1**. Traffic surveillance systems use detectors and video equipment to support the most advanced freeway management applications. Traffic control measures on freeway entrance ramps, such as ramp meters, can use sensor data to optimize freeway travel speeds and ramp meter wait times. Lane management applications can address the effective capacity of freeways and promote the use of high-occupancy commute modes. Special event transportation management systems can help control the impact of congestion at stadiums or convention centers. In areas with frequent events, large changeable destination signs or other lane control equipment can be installed. In areas with occasional or one-time events, portable equipment can help smooth traffic flow. Advanced communications have improved the dissemination of information to the traveling public. Motorists are now able to receive relevant information on location-specific traffic conditions in a number of ways, including dynamic message signs, highway advisory radio, in-vehicle signing, or specialized information transmitted only to a specific set of vehicles. Other methods of providing traveler information, including those covering multiple modes or travel corridors, are discussed in **Section 2.7–Traveler Information**. In the application area of automated enforcement, enforcement of speed limits and aggressive driving laws can lead to safety benefits.



For a summary of freeway management systems deployments across the U.S., refer to **www.itsdeployment.its.dot.gov**.

Table 2.2.1 provides information on the benefits and costs of freeway management systems. Information provided on the impacts of these systems is indicated using the symbols in the Impact Legend at the bottom corner of each page.

Intelligent Infrastructure



Freeway Management Systems

- **Traffic Surveillance**
- **Ramp Control**
  - Ramp Metering
  - Ramp Closures
  - Priority Access
- **Lane Management**
  - HOV Facilities
  - Reversible Flow Lanes
  - Pricing
  - Lane Control
  - Variable Speed Limits
  - Emergency Evacuation
- **Special Event Trans. Mgmt.**
  - Occasional Events
  - Frequent Events
  - Other Events
  - Temporary TMCs
- **Information Dissemination**
  - Dynamic Message Signs (DMS)
  - In-Vehicle Systems (IVS)
  - Highway Advisory Radio (HAR)
- **Enforcement**
  - Speed Enforcement
  - High Occupancy Vehicles (HOV)
  - Ramp Meter Enforcement

Figure 2.2.1
Taxonomy for Freeway Management Systems

TABLE 2.2.1
BENEFITS AND COSTS OF FREEWAY MANAGEMENT SYSTEMS

Traffic Surveillance		
Benefits		
Supporting role, no benefits information.		
Costs		
Unit Costs Database	Roadside Telecommunications subsystem Roadside Detection subsystem Transportation Management Center subsystem	See Appendix A
System Cost	The TRANSCOM's System for Managing Incidents and Traffic (TRANSMIT) system operating in New Jersey and New York utilizes electronic toll collection and traffic management equipment compatible with the E-ZPass System for traffic surveillance and incident detection. The system consists of a central computer and communications system and approximately 22 roadside detection stations.[68]	Capital costs: **$975,200** (1996) Annual O&M costs: **$300,680** (1996)

Impact Legend
- ++ substantial positive impacts
- + positive impacts
- ○ negligible impact
- +/– mixed results
- ? not enough data
- – negative impacts

Ramp Control: Ramp Metering

Benefits

Goal Area	# of Studies	Impact	Example
Safety	6	+	A study of the six-week shutdown of the ramp meters in Minneapolis-St. Paul, Minnesota, found that ramp meters were responsible for a 21% crash reduction.[7]
Mobility	7	++	Two studies in Minneapolis-St. Paul, Minnesota, and one in Long Island, New York, place mainline speed increases on freeways with ramp metering between 8% and 26%.[7,9,69]
Capacity/ Throughput	4	++	The Minneapolis-St. Paul, Minnesota, shutdown study found that freeway volumes were 10% higher with ramp meters than they were during the shutdown.[7]
Customer Satisfaction	3	+	Support for complete shutdown of the Minneapolis-St. Paul, Minnesota, ramp metering system dropped from 21% in 2000 to just 14% of survey respondents after implementation of a modified operating strategy in 2001.[7] 59% of survey respondents in Glasgow, Scotland, found ramp metering to be a helpful strategy.[5]
Energy/ Environment	1	?	A simulation study of the Minneapolis-St. Paul, Minnesota, system found 2-55% fuel savings for vehicles traveling along two modeled corridors under varying levels of travel demand.[9]

Costs

Unit Costs Database	Roadside Control subsystem	See Appendix A
System Cost	Colorado DOT (CDOT) has implemented ramp metering to regulate the flow of traffic onto freeways as part of the T-REX (Transportation Expansion) project.[10, 11]	Cost: **$50,000** for each site installed with controller (2001)
System Cost	The cost of Minnesota DOT (Mn/DOT) ramp metering operations in fiscal year (FY) 2000 included staff to monitor and adjust meter settings, conduct field reviews, and respond to inquiries from the public and media.[70]	Annual O&M cost: **$210,000** (2001)

At the conclusion of the ramp meter shutdown experiment in Minneapolis-St. Paul, Minnesota, during December of 2000, the following interim ramp metering strategies were implemented:

- A number of meters were left turned off;
- Ramp meter operations were reduced to four hours each day; and
- Faster metering rates were used.

A follow-up evaluation of the freeway system found that despite the resumption of ramp metering at select locations in each corridor, traffic operations and safety performance remained degraded and were unable to be restored to pre-shutdown (full metering) levels by the end of the evaluation period. The number of crashes recorded during the first seven months of 2001 (post-shutdown period with reduced ramp metering operation) was 15% higher than the average number of crashes measured for the first seven months of 1998, 1999, and 2000 (fully metered period). Freeway travel speeds

continued on next page

Impact Legend

- ++ substantial positive impacts
- \+ positive impacts
- o negligible impact
- +/– mixed results
- ? not enough data
- – negative impacts

continued from last page

under the modified operating strategy decreased 5-10% when compared to the pre-shutdown strategy and freeway travel times increased 5-10%. The Phase II report ended the ramp meter study; however, the Mn/DOT will continue to monitor performance and make changes to ramp meter timing as necessary based on evolving traffic conditions.[8]

Lane Management: Lane Control

Benefits

Goal Area	# of Studies	Impact	Example
Safety	1	?	Traffic surveillance, lane control signs, variable speed limits, and dynamic message signs in Amsterdam, the Netherlands, have led to a 23% decline in the accident rate.[62]

Costs

Unit Costs Database	No data to report.	
System Cost	No data to report.	

Lane Management: Variable Speed Limits

Benefits

Goal Area	# of Studies	Impact	Example
Safety	1	?	In England, variable speed limits supplemented with automated speed enforcement have reduced rear-end accidents on approaches to freeway queues 25% - 30%.[62]
Capacity/ Throughput	1	?	Combined with automated speed limit enforcement, an English variable speed limit system has increased freeway capacity 5% - 10%.[62]

Costs

Unit Costs Database	Roadside Telecommunications subsystem Roadside Control subsystem Roadside Detection subsystem Roadside Information subsystem	See Appendix A
System Cost	Washington State DOT (WSDOT) implemented Travel Aid, a variable speed limit (VSL) system that changes as the weather does, along the Snoqualmie Pass (I-90) east of Seattle, Washington. Approximately 13 miles are operated as VSL during the winter months. The system consists of radar detection, six weather stations, nine dynamic message signs, and radio and microwave transmission systems.[18, 71, 72]	Design and implementation cost: **$5** million (1997)

Impact Legend

- ++ substantial positive impacts
- \+ positive impacts
- ○ negligible impact
- +/– mixed results
- ? not enough data
- – negative impacts

Special Event Transportation Management

Benefits

No data to report.

Costs

Unit Costs Database	Roadside Telecommunications subsystem Roadside Information subsystem Parking Management subsystem	See Appendix A
System Cost	No data to report.	

Information Dissemination

Benefits

Goal Area	# of Studies	Impact	Example
Safety	1	?	A San Antonio, Texas, deployment of dynamic message signs, combined with an incident management program resulted in a 2.8% decrease in crashes.[19]
Mobility	6	+	A simulation study of the system deployed on the John C. Lodge freeway in Detroit, Michigan, estimated that HAR and dynamic message signs in combination with ramp metering may reduce vehicle delay by up to 22%.[97]
Customer Satisfaction	3	+	European studies find 30% - 90% of travelers notice dynamic message signs,[51] and a Glasgow, Scotland, survey found 40% of respondents changed route as recommended by dynamic message signs.[5]

Costs

Unit Costs Database	Roadside Telecommunications subsystem Roadside Information subsystem	See Appendix A
System Cost	Metropolitan Detroit, Michigan, has deployed approximately 65 dynamic message signs since the early 1980s. The total cost includes expansion of the signs from the initial installation and improving the information system.[73]	Cost of expanding to 65 signs and improving system: **$49** million O&M cost for 2001: **$6** million O&M cost for 2002: **$7** million
System Cost	Washington State DOT has implemented three highway advisory radios along the Blewett/Stevens Pass to provide weather and road condition information to travelers and maintenance crews. Annual O&M costs are based on prior experience to operate and maintain.[11]	Average cost of equipment (including installation): **$20,000** (2001) Annual O&M cost: **$1,000** (2001)

Impact Legend

- ++ substantial positive impacts
- + positive impacts
- ○ negligible impact
- +/− mixed results
- ? not enough data
- − negative impacts

Enforcement

Benefits

Goal Area	# of Studies	Impact	Example
Safety	8	++	A study of speed enforcement cameras along segments of Norwegian highways which met certain warrants regarding traffic speeds and accident rates prior to the deployment of cameras found a 26% decline in injury accidents.[74]
Customer Satisfaction	2	?	82% of survey respondents in the Washington, DC, area favored video technology used to enforce aggressive driving laws such as speeding and following too closely.[75]

Costs

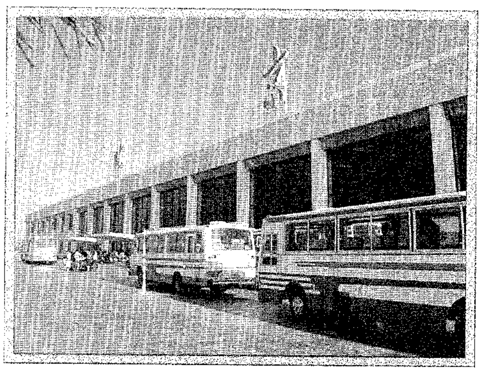
Unit Costs Database	Roadside Telecommunications subsystem Roadside Detection subsystem	See Appendix A
System Cost	An automatic speed enforcement system was implemented on a 50-km stretch of highway in Finland. The system consisted of camera equipment and detectors at 12 camera sites.[65]	Cost: **178,000** euros (Approximately **$178,000** USD)

Impact Legend

- ++ substantial positive impacts
- + positive impacts
- ○ negligible impact
- +/– mixed results
- ? not enough data
- – negative impacts

2.3 Transit Management Systems

Transit ITS services include a number of ITS applications that can help transit agencies increase safety and improve the operational efficiency of the nation's transit systems. Advanced software and communications enable data as well as voice to be transferred between transit management centers and transit vehicles for increased safety and security, improved transit demand management, and more efficient fleet operations. Transit management centers in several cities now monitor in-vehicle and in-terminal surveillance systems to improve quality of service and improve the safety and security of passengers and operators.



Transit demand management services increase public access to transit resources where coverage is limited. Fleet management systems improve transit reliability through implementation of automated vehicle location (AVL) and computer-aided dispatch (CAD) systems which can reduce passenger wait times. These systems have sometimes been implemented with in-vehicle self-diagnostic equipment to automatically alert maintenance personnel of potential problems.

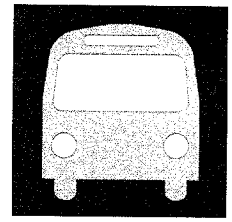
Overall, the dissemination of transit information has improved. Passengers can use a wide variety of communication devices to confirm scheduling information, improve transfer coordination, and reduce wait times.

Figure 2.3.1 shows the classification of benefits and costs information for transit management systems. Transit signal priority and electronic payment systems, discussed in sections 2.1 and 2.6, respectively, also provide significant benefits to transit operations.

For a summary of transit management systems deployments across the U.S., refer to **www.itsdeployment.its.dot.gov.**

Table 2.3.1 provides information on the benefits and costs of transit management systems. Information provided on the impacts of these is indicated using the symbols in the Impact Legend at the bottom corner of each page.

Intelligent Infrastructure



Transit Management Systems

- **Safety & Security**
  - In-Vehicle Surveillance
  - Facility Surveillance
  - Employee Credentialing
  - Remote Disabling Systems
- **Transit Demand Management**
  - Ride Sharing/Matching
  - Dynamic Routing/ Scheduling
  - Service Coordination
- **Fleet Management**
  - AVL/CAD
  - Maintenance
  - Planning
- **Information Dissemination**
  - In-Vehicle Systems (IVS)
  - In-Terminal/Wayside
  - Internet/Wireless/Phone

Figure 2.3.1
Taxonomy for Transit Management Systems

TABLE 2.3.1
BENEFITS AND COSTS OF TRANSIT MANAGEMENT SYSTEMS

Safety & Security: On-Vehicle Surveillance			
Benefits			
Goal Area	**# of Studies**	**Impact**	**Example**
Customer Satisfaction	1	?	The Ann Arbor, Michigan, transit onboard camera systems were often noticed by passengers, but the system only provided a significant feeling of additional security when respondents were traveling at night.[76]
Costs			
Unit Costs Database	Transit Management Center subsystem Transit Vehicle On-Board subsystem		See Appendix A
System Cost	The Pinellas Suncoast Transit Authority operating in Clearwater and St. Petersburg, Florida, has equipped 16 of its buses with five cameras and one microphone each for recording of video and audio activity onboard the bus. The transit agency plans to use a $1.1 million grant to equip 100 more buses.[77]		Cost per bus: **$9,700** (2001)

Safety & Security: Facility Surveillance			
Benefits			
Goal Area	**# of Studies**	**Impact**	**Example**
Customer Satisfaction	1	?	When respondents in Ann Arbor, Michigan, rated the degree to which improvements increased their sense of security, police presence showed the greatest influence, followed closely by increased lighting. Emergency phones and video cameras had less influence.[76]
Costs			
Unit Costs Database	Transit Management Center subsystem Transit Vehicle On-Board subsystem Remote Location subsystem		See Appendix A
System Cost	No data to report.		

Impact Legend
- ++ substantial positive impacts
- + positive impacts
- ○ negligible impact
- +/– mixed results
- ? not enough data
- – negative impacts

Transit Demand Management: Dynamic Routing/Scheduling

Goal Area	# of Studies	Impact	Example
Benefits			
Mobility	1	?	In Eindhoven, The Netherlands, onboard computers recorded daily transit performance. This information was used to plan minimum transit route times, and increase schedule reliability.[78]
Productivity	4	+	In San Jose, California, the Outreach paratransit program installed AVL on 40 vehicles. The automated scheduling and routing system enabled shared rides to increase from 38% to 55%, allowing the fleet size to decrease from 200 to 130 vehicles.[79]
Customer Satisfaction	1	?	A paratransit driver in San Jose, California, commented that she was satisfied with the system. In particular, she cited its usefulness in settling driver-passenger disputes concerning on-time performance.[79]

Costs		
Unit Costs Database	Transit Management Center subsystem Transit Vehicle On-Board subsystem	See Appendix A
System Cost	The cost of demand-responsive operational software and computer-aided dispatching systems varies depending on the transit mode, application, and system functionality. Low-end systems can facilitate scheduling, accounting, and report generation activities. High-end systems generally have more advanced transit demand management features and can automate passenger registration, schedule trips in real time, interface with GIS and AVL systems, and communicate with digital mobile messaging systems.[80]	Cost range: **$10,000-$50,000+** per system implementation

Transit Demand Management: Service Coordination

Goal Area	# of Studies	Impact	Example
Benefits			
Productivity	3	+	Travel dispatch centers in Europe used service coordination systems to decrease paratransit operations costs 2-3%. This compared favorably to the previous 15% annual increase.[51]

Costs		
Unit Costs Database	Transit Management Center subsystem Transit Vehicle On-Board subsystem	See Appendix A
System Cost	No data to report.	

Impact Legend
- ++ substantial positive impacts
- + positive impacts
- o negligible impact
- +/– mixed results
- ? not enough data
- – negative impacts

2.3 Transit Management Systems

In 1997, the Ann Arbor Transportation Authority, in Ann Arbor, Michigan, began implementing an advanced public transportation system for its fixed route and paratransit bus operations. The system integrated a number of applications. For paratransit vehicles, the system facilitated reservations and scheduling. For transit vehicles, AVL was deployed to track vehicle location using GPS and in-vehicle mobile data terminals. These in-vehicle terminals were installed to automatically monitor vehicle location, schedule adherence, passenger counts, and engine performance. If a bus was behind schedule or was developing engine problems, the in-vehicle terminal would automatically notify the operations center and ask connecting buses to hold for late transfers. Updated schedules were then made available to passengers via the internet, telephone, or on kiosks at selected bus stops. To improve safety on each route, onboard camera surveillance systems were also installed. Drivers were able to activate onboard emergency systems to alert

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Fleet Management: AVL/CAD

Benefits

Goal Area	# of Studies	Impact	Example
Productivity	7	++	After an extended analysis of travel times, Kansas City, Missouri, used an AVL/CAD system to reduce up to 10% of the vehicles required for some bus routes with no reduction in customer service.[82]
Customer Satisfaction	3	+	The GPS-based vehicle location system in Denver, Colorado, rated very well with Regional Transportation District (RTD) dispatchers. Operators and dispatchers were able to communicate more quickly and efficiently. Approximately 80% of dispatchers found the system "easy" or "very easy" to use, and about 50% of operators and street supervisors felt likewise.[12]
Mobility	8	++	The Denver, Colorado, RTD implemented its AVL system to improve bus service, and succeeded in decreasing passenger late arrivals by 21%.[12]

Costs

Unit Costs Database	Roadside Telecommunications subsystem Transit Management Center subsystem Transit Vehicle On-Board subsystem	See Appendix A
System Cost	The AVL system installed by the Denver, Colorado, RTD on its 1,355 vehicle fleet is GPS-based. The capital cost includes system software, dispatch center hardware, in-vehicle hardware, field communication equipment, initial training, and planning and implementation.[12]	Capital cost: **$10.4** million (approximately) Annual O&M cost: **$1.9** million (approximately) (1997)

Fleet Management: Maintenance

Benefits

Goal Area	# of Studies	Impact	Example
Productivity	2	+	A demonstration project in Valencia, Spain, incorporated remote maintenance bus monitoring with dynamic scheduling. The system decreased non-revenue service time through a 20 - 30% reduction in the time to detect and correct vehicle faults.[51]

Costs

Unit Costs Database	Transit Management Center subsystem Transit Vehicle On-Board subsystem	See Appendix A
System Cost	No data to report.	

Impact Legend

- ++ substantial positive impacts
- + positive impacts
- ○ negligible impact
- +/− mixed results
- ? not enough data
- − negative impacts

Information Dissemination: In-Vehicle Systems

Benefits

No data to report.

Costs

Unit Costs Database	Transit Management Center subsystem Transit Vehicle On-Board subsystem	See Appendix A
System Cost	Transport of Rockland, New York, has equipped the first three of 27 buses with equipment that announces and displays the route and each stop along the route.[83]	Cost per bus: **$7,000** (2000)

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dispatchers of life-threatening situations. The system enabled dispatchers to quickly alert the authorities and communicate with passengers using an in-vehicle public address system. The cost of the overall integrated transit management system was about $35,200 per bus for a fleet of 75 buses.[82] (1995)

Information Dissemination: In-Terminal/Wayside

Benefits

Goal Area	# of Studies	Impact	Example
Customer Satisfaction	2	+	In-terminal real-time transit information displays were regarded as useful by 95% of those surveyed in Helsinki, Finland. The most desirable features were displays of remaining wait time and knowing if an expected vehicle had already passed.[49]

Costs

Unit Costs Database	Roadside Telecommunications subsystem Transit Management Center subsystem Transit Vehicle On-Board subsystem	See Appendix A
System Cost	Transit riders at Bellevue and Northgate Transit Centers (Seattle, Washington) are provided with bus arrival/departure times, bay number, and expected actual departure times for all bus routes using the transfer center. The system, TransitWatch, obtains actual times from an AVI system and presents the information on monitors at the transit centers. Approximately 12% of the capital cost and 25% of the O&M cost were shared with other Seattle Smart Trek Model Deployment Initiative (MMDI) projects.[20]	Capital cost: **$722,877** (1998) Annual O&M cost: **$179,652** (1998)

Impact Legend
- + + substantial positive impacts
- + positive impacts
- ○ negligible impact
- +/- mixed results
- ? not enough data
- – negative impacts

Information Dissemination: Internet/Wireless/Phone

Benefits

Goal Area	# of Studies	Impact	Example
Customer Satisfaction	1	?	The ROUTES (Rail, Omnibus, Underground, Travel Enquiry System) computerized travel enquiry system used by the London Transport in London, England, helped 13% of travelers change their travel modes to transit, which generated an estimated 1.3 million pounds sterling (approximately $2 million USD) of additional revenue for bus companies, 1.2 million pounds (approximately $1.9 million USD) for the underground, and 1 million pounds (approximately $1.6 million USD) for railways.[84]

Costs

Unit Costs Database	Transit Management Center subsystem Transit Vehicle On-Board subsystem	See Appendix A
System Cost	BusView is a component of Metro Online, the King County, Washington, transit website. BusView displays bus progress and routes on a map. Roughly 25% of the capital cost and 25% of the O&M cost were shared with other Seattle Smart Trek MMDI projects.[20]	Capital cost: **$333,118** (1998) Annual O&M cost: **$175,552** (1998)
System Cost	The Regional Transportation District in Denver, Colorado, has implemented a voice recognition call-in system called Talk-n-Ride which enables transit riders to call a toll-free number and check if their bus or train is on time and the scheduled arrivals of the next three buses. The cost to implement the system does not include the cost for tracking bus location.[85]	System cost: **$40,000** (2001)

Impact Legend

- ++ substantial positive impacts
- \+ positive impacts
- o negligible impact
- +/– mixed results
- ? not enough data
- – negative impacts

2.4 Incident Management Systems

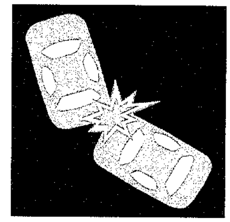
Incident management systems can reduce the effects of incident-related congestion by decreasing the time to detect incidents, reducing the time for responding vehicles to arrive, and decreasing the time required for traffic to return to normal conditions. The classification of benefit and cost data for incident management systems is summarized in **Figure 2.4.1**.

A variety of surveillance and detection technologies can help detect incidents quickly, including inductive loop or acoustic roadway detectors, and camera systems providing frequent still images or full-motion video. Information from wireless enhanced 911 systems, mayday and automated collision notification systems, as well as roadside call boxes can also help incident management system personnel identify incidents quickly. Mobilization and response may include automated vehicle location and computer-aided dispatch systems, as well as response routing systems, to help incident response teams arrive swiftly. Motorist assistance patrols, occasionally initiated prior to the emergence of ITS technologies, are now frequently incorporated into traffic management systems. These patrols significantly reduce the time to clear incidents, especially minor ones.

Several components of incident management systems help travelers safely negotiate travel around incidents on the roadway and facilitate the rapid and safe clearance of incidents and reopening of travel lanes. In some locations, incident management personnel can directly post incident-related information to roadside traveler information devices such as dynamic message signs or highway advisory radio. On-site, or transportation management center-based personnel can also relay messages to traveler information, freeway management, or arterial management systems, providing incident information to travelers via additional means including 511 systems and traveler information websites. Several technologies are available to speed the investigation of incident scenes and record necessary information for later analysis. Temporary traffic control devices help ensure the safety of incident responders and provide for the safe travel of vehicles around the incident site.

It is generally understood that incident management systems are implemented concurrently with freeway management systems, but it is important to keep in mind that arterials can be included in incident management programs as well. Coverage of arterials by incident management programs is increasing, particularly in areas with well-established programs.

Intelligent Infrastructure



Incident Management Systems

- **Surveillance & Detection**
  - Detectors
  - Imaging/Video
  - Wireless E911
  - Mayday/ACN
  - Call Boxes
  - Traveler Reported
- **Mobilization & Response**
  - AVL/CAD
  - Response Routing
  - Motorist Assistance Patrols
- **Information Dissemination**
  - Dynamic Message Signs (DMS)
  - Highway Advisory Radio (HAR)
- **Clearance & Recovery**
  - Investigation
  - Video
  - Temporary Traffic Control

Figure 2.4.1
Taxonomy for Incident Management Systems

Table 2.4.1 summarizes much of the data collected for incident management impacts. Incident management programs have shown the potential to reduce the number of accidents and the time required for the detection and clearance of incidents. These programs show significant savings in the cost of congestion and are cost-effective. In addition, the public response to these programs has been very positive.

For a summary of incident management systems deployments across the U.S., refer to **www.itsdeployment.its.dot.gov**.

Table 2.4.1 provides information on the benefits and costs of incident management systems. Information provided on the impacts of these systems is indicated using the symbols in the Impact Legend at the bottom of each page.

Table 2.4.1
Benefits and Costs of Incident Management Systems

Surveillance & Detection		
Benefits		
No data to report.		
Costs		
Unit Costs Database	Roadside Telecommunication subsystem Roadside Detection subsystem Transportation Management Center subsystem	See Appendix A
System Cost	The Georgia DOT installed 147 call boxes along a 39-mile rural section of I-185 as part of a pilot project. The total project cost included 147 call boxes, 3 computer systems at the answer center, and 1 computer at the maintenance center.[86]	Total project cost: **$911,873** Average cost per call box including construction: **$5,590** (1999) Annual O&M breakdown: Maintenance cost for one year: **$51,450** (1999) Cellular service cost for one year: **$38,808** (1999)

Impact Legend
++ substantial positive impacts
\+ positive impacts
o negligible impact
+/– mixed results
? not enough data
– negative impacts

Mobilization & Response

Benefits

Goal Area	# of Studies	Impact	Example
Safety	6	+	In San Antonio, Texas, combined incident management and freeway management systems along the Medical Center corridor reduced crashes 2.8%.[19]
Mobility	9	++	A study of the Coordinated Highways Action Response Team (CHART) in Maryland found that the system reduced average incident duration 57% in 2000 and 55% in 1999.[13]
Customer Satisfaction	1	+	Motorist assistance patrols are well-received by the public. The Virginia Department of Transportation has published hundreds of "thank you" letters received regarding their Safety Service Patrol.[17]
Productivity	5	+	Delay savings identified in studies of systems in Minnesota, Colorado, and Indiana represent benefits of $1.2 to $1.8 million.[14, 15, 16]
Energy/ Environment	5	+	Reductions in incident-related delay also lead to fuel savings and related emissions reductions. A simulation study of the San Antonio, Texas, TransGuide system of freeway and incident management found the system saved an average 2,600 gallons of fuel during major incidents.[87]

Costs

Unit Costs Database	Transportation Management Center subsystem	See Appendix A
System Cost	Dane County, Wisconsin, implemented an interagency dispatch and reporting coordination system to improve response to incidents and emergencies. Police vehicles are equipped with on-board computers used to transmit incident data to a central dispatching database.[18]	Cost per vehicle: **$8,000-$10,000**
System Cost	Colorado DOT has implemented enhanced courtesy patrols in the T-REX (Transportation Expansion) construction zone to assist stranded motorists.[10, 11]	Cost: **$55** per vehicle hour (2001)

In San Antonio, Texas, an integrated freeway/incident management system was developed as part of a freeway expansion project. The project covered a 28.9-mile stretch of I-10, I-410, and US 281 in the northern region of San Antonio. The cost of the freeway and incident management expansion project was approximately $26.6 million with an estimated annual O&M cost of $852,000. The majority of the cost was for surveillance, detection, and information equipment and communications hardware. Detection technologies such as acoustic sensors, loops, and digital detectors, closed circuit television (CCTV) cameras, dynamic message signs and lane control systems, and supporting fiber optic communications infrastructure were deployed. The cost of mobilization (e.g., keeping traffic moving during deployment) during the expansion was approximately $2 million. This cost was kept low based on the planning decision to deploy the ITS components as part of the highway reconstruction.[19] (1998)

Impact Legend
- ++ substantial positive impacts
- \+ positive impacts
- ○ negligible impact
- +/– mixed results
- ? not enough data
- – negative impacts

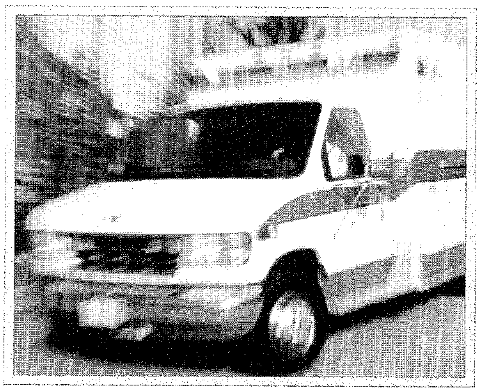
Information Dissemination		
Benefits		
No data to report.		
Costs		
Unit Costs Database	Roadside Information subsystem	See Appendix A
System Cost	Metropolitan Detroit has deployed approximately 65 dynamic message signs since the early 1980s. The total cost includes expansion of the signs from the initial installation and improving the information system.[73]	Cost of expanding to 65 signs and improving system: **$49** million O&M cost for 2001: **$6** million O&M cost for 2002: **$7** million

Clearance & Recovery: Investigation		
Benefits		
No data to report.		
Costs		
Unit Costs Database	Transportation Management subsystem	See Appendix A
System Cost	Computer-aided incident investigation equipment was purchased as part of the Phoenix, Arizona, MMDI to reduce incident clearance time and improve the quality of accident investigations. The initial cost of the project included hardware, software, and training.[57]	Total start-up cost: **$147,000** (1998) Annual O&M costs: **$4,305** (not including labor) (1998)
System Cost	Minnesota DOT and the Minnesota State Patrol have implemented a pilot automated field reporting system that enables law enforcement officials to use an in-vehicle computer to record and submit incident information.[18]	Cost per vehicle: **$8,000-$10,000**

Impact Legend
- ++ substantial positive impacts
- + positive impacts
- ○ negligible impact
- +/– mixed results
- ? not enough data
- – negative impacts

2.5 Emergency Management Systems

Benefits of emergency management include those derived from improved notification, dispatch, and guidance of emergency responders to the scene of an incident. **Figure 2.5.1** shows the current classification of benefits and costs for emergency management systems. These benefits are sometimes highly dependent on the ability of an incident management system to detect the need for emergency management on the transportation network. ITS applications in emergency management cover hazardous materials management, the deployment of emergency medical systems, and large- and small-scale emergency response and evacuation operations. Each of these systems can improve public safety by decreasing response times and increasing the operational efficiency of safety professionals during emergency situations, such as hurricane evacuations.

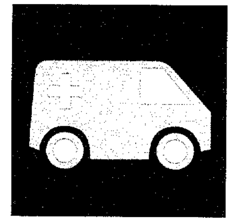


Across the U.S., federal, state, and local governments are working to support first responders, secure our borders, and improve technology for national security. As these programs come to fruition, improved information will become available on the benefits of ITS for emergency management activities.

Advanced automated collision notification (ACN) and telemedicine address the detection of and response to incidents such as vehicle accidents or other accidents requiring emergency responders. In rural areas, response time for emergency medical services is greater than in metropolitan areas, resulting in more severe consequences or impacts. Advanced automated collision notification systems can notify emergency personnel and provide them with valuable information on the crash, including location, crash characteristics, and possibly relevant medical information regarding the vehicle occupants. Telemedicine systems provide a link between responding ambulances and nearby emergency medical facilities, enabling doctors to advise emergency medical personnel regarding treatment of patients en route to the hospital.

Evacuation operations often require a coordinated emergency response involving multiple agencies, various emergency centers, and numerous response plans. Response management may include the tracking of emergency vehicle fleets using automated vehicle location (AVL) technology and two-way communications

Intelligent Infrastructure



Emergency Management Systems

- **Hazardous Materials Management**
- **Emergency Medical Services**
  - Advanced ACN
  - Telemedicine
- **Response & Recovery**
  - Evacuation Operations
  - Response Management

Figure 2.5.1
Taxonomy for Emergency Management Systems

between emergency vehicles and dispatchers. Integration with traffic and transit management systems enables emergency information to be shared between public and private agencies and the traveling public.

For a summary of emergency management systems deployments across the U.S., refer to **www.itsdeployment.its.dot.gov**.

Table 2.5.1 provides information on the benefits and costs of emergency management systems. Information provided on the impacts of these systems is indicated using the symbols in the Impact Legend at the bottom corner of each page.

Table 2.5.1 Benefits and Costs of Emergency Management Systems

Hazardous Materials Management		
Benefits		
No data to report.		
Costs		
Unit Costs Database	Emergency Response Center subsystem Emergency Vehicle On-Board subsystem	See Appendix A
System Cost	No data to report.	

Emergency Medical Services: Advanced ACN		
Benefits		
No data to report.		
Costs		
Unit Costs Database	Emergency Response Center subsystem Emergency Vehicle On-Board subsystem Vehicle On-Board subsystem	See Appendix A
System Cost	No data to report.	

Impact Legend
- ++ substantial positive impacts
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- ○ negligible impact
- +/– mixed results
- ? not enough data
- – negative impacts

Emergency Medical Services: Telemedicine

Benefits			
Goal Area	# of Studies	Impact	Example
Customer Satisfaction	1	+/–	The LifeLink project in San Antonio, Texas, enabled emergency room doctors to communicate with emergency medical technicians (EMTs) using 2-way video, audio, and data communications. EMTs and doctors had mixed opinions about the system; however, it was expected that this technology would have more positive impacts in rural areas.[19]

Costs		
Unit Costs Database	Roadside Telecommunications subsystem Emergency Response Center subsystem Emergency Vehicle On-Board subsystem	See Appendix A
System Cost	The LifeLink project (San Antonio, Texas) was deployed to provide improved emergency services. The system supports voice and video teleconferencing between University Hospital and 10 of the ambulances in the San Antonio Fire Department. Much of the cost of the project is attributed to research and development.[19]	Project cost: **$3.25** million (1998) Annual O&M cost: **$25,325** (1998)

Response and Recovery: Response Management

Benefits
No data to report.

Costs		
Unit Costs Database	Emergency Response Center subsystem Emergency Vehicle On-Board subsystem	See Appendix A
System Cost	To overcome the lack of shared communication among Emergency Operations Centers (EOCs) in the Seattle, Washington, metropolitan area, the Smart Trek project purchased and distributed to each EOC communications equipment that operated on the same frequency. The project cost included the purchase of sixteen 800 MHz radios, three repeater station upgrades, other equipment, and planning and development labor costs.[20]	Cost: **$151,700** (1998) Annual O&M cost: **$2,860** (1998)

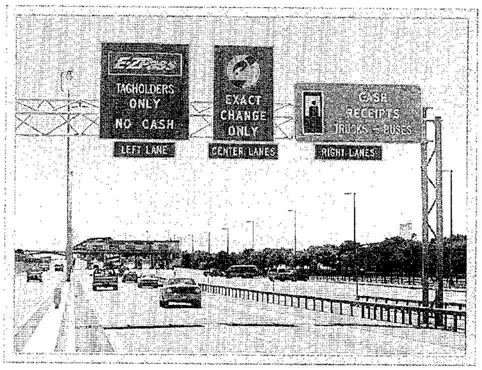
Palm Beach County, Florida, deployed an emergency response management system to reduce emergency vehicle response times. The system used GPS technology and emergency vehicle signal preemption to enable dispatchers to determine which vehicles were closest to an emergency. The cost of the system was about $4,000 per intersection and $2,000 per vehicle.[88] (1997)

Impact Legend
- ++ substantial positive impacts
- + positive impacts
- o negligible impact
- +/– mixed results
- ? not enough data
- – negative impacts

2.6 Electronic Payment Systems

Electronic payment systems employ various communication and electronic technologies to facilitate commerce between travelers and transportation agencies. **Figure 2.6.1** outlines the most common systems deployed.

Electronic toll collection (ETC) supports the collection of payment at toll plazas using automated systems to increase the operational efficiency and convenience of toll collection. ETC is one of the most successful ITS applications with numerous benefits related to delay reductions, improved throughput, and reduced fuel consumption and vehicle emissions at toll plazas. Studies have also documented increases in crashes at toll plazas with ETC, likely due to driver uncertainty regarding plaza configuration and speed variability between vehicles with and without ETC transponders. The most advanced ETC technologies can identify and process vehicles traveling at high speeds. This enables cars to travel on the mainline without having to slow down and negotiate tollbooths.



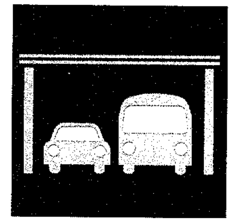
Transit fare payment systems can provide increased convenience to customers and generate significant cost savings to transportation agencies by increasing the efficiency of money-handling processes and improving administrative controls.

Multi-use payment systems can make transit payment more convenient. Payment for bus, rail, and other public or private sector goods and services can be made simply by passing a smart-card-sized device over an automated transaction point located at terminal gates, or at check-out counters and phone booths of participating merchants located near transit stations. Multi-use systems may also incorporate the ability to pay highway tolls with the same card. Additional performance data on these systems should become available as these systems are deployed.

For a summary of electronic payment systems deployments across the U.S., refer to **www.itsdeployment.its.dot.gov.**

Table 2.6.1 provides information on the benefits and costs of electronic payment systems. Information provided on the impacts of these systems is indicated using the symbols in the Impact Legend at the bottom corner of each page.

Intelligent Infrastructure



Electronic Payment Systems

- **Toll Collection**
- **Transit Fare Payment**
- **Multi-use Payment**

Figure 2.6.1
Taxonomy for Electronic Payment Systems

Table 2.6.1
Benefits and Costs of Electronic Payment Systems

Toll Collection			
Benefits			
Goal Area	# of Studies	Impact	Example
Safety	2	–	In Florida, driver uncertainty about congestion at Express Pass (E-PASS) toll stations contributed to a 48% increase in accidents.[89]
Mobility	4	++	Implementation of the E-ZPass system by the New Jersey Turnpike Authority (NJTA) reduced delay for all vehicles at toll plazas by 85%.[90]
Capacity/ Throughput	1	+	A study of ETC on the Tappan Zee Bridge in New York City showed an ETC lane could process 1,000 vehicles/hour (vph), while a manual lane could handle only 400 - 450 vph.[91]
Customer Satisfaction	1	?	20% of travelers on two bridges in Lee County, Florida, adjusted their departure times as a result of value pricing and electronic tolls.[92]
Productivity	3	+	Based on changes in traffic conditions after deployment of E-ZPass, passenger cars on the New Jersey turnpike saved an estimated $19 million in delay costs and $1.5 million in fuel costs each year.[90]
Energy/ Environment	4	+/–	Model calculations of emissions using the EPA Mobile-5a model and traffic field data indicated ETC decreased CO by 7.3%, decreased hydrocarbons by 7.2%, and increased NOx by 33.8% at the Holland East Toll Plaza in Florida. NOx increased as a result of higher engine speeds.[93]
Costs			
Unit Costs Database	Toll Plaza subsystem Toll Administration subsystem		See Appendix A
System Cost	The cost for the Oklahoma Turnpike Authority to operate an electronic toll collection lane is approximately 91% less than to staff and operate a traditional toll lane.[94]		Annual O&M cost: **$16,000** per lane

Impact Legend
- ++ substantial positive impacts
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- ○ negligible impact
- +/– mixed results
- ? not enough data
- – negative impacts

Transit Fare Payment

Benefits			
Goal Area	**# of Studies**	**Impact**	**Example**
Customer Satisfaction	3	+	Chicago, Illinois, transit riders participating in a pilot program rated convenience, rail use, and speed the most preferred features of the SmartCard.[95]
Productivity	3	+	The smart card electronic payment system in Ventura, California, saved an estimated $9.5 million per year in reduced fare evasion, $5 million in reduced data collection costs, and $990,000 by eliminating transfer slips.[21]
Costs			
Unit Costs Database	Transit Management Center subsystem Transit Vehicle On-Board subsystem		See Appendix A
System Cost	The Ventura County Transportation Commission, in California, implemented an electronic fare payment system on its buses. The "Go Ventura" card allows transit riders to use a smart card for fare payment on buses run by the county's six transit systems.[22]		Project cost: **$1.7** million (2001)

Transit riders in Chicago, Illinois, were surveyed to evaluate the technological feasibility and customer acceptance of the SmartCard fare payment system. The SmartCard differs from the magnetic stripe farecard deployed across the Chicago Transit Authority (CTA) system in 1997 in that passengers need only pass the card in close proximity to a radio signal reader mounted on turnstiles and bus fareboxes. 3,500 CTA customers purchased the $5 cards and participated in the pilot program, and 1,300 customer surveys were evaluated. Respondents most liked features related to convenience, rail use, and speed. 21% rated convenience over the magnetic stripe card as their single favorite feature of the system; 15% liked being able to use the cards for train travel; 13% liked the reduced time to register rail fare; and, 8% liked the convenience of the system over using cash to pay fares. The least-liked features were the $5 fee, the need to add value to the card after paying the $5 fee, and inaccuracies in calculating bonus fare when adding $10 or more to the card. Features that would

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simplify adding value to the card were the most popular potential additional features of the program. Most desired were: the ability to recharge via the Internet and credit card (desired most by 17% of respondents); the ability to pay fares on the Metra commuter rail system as well as CTA (11%); auto-recharge via credit card (8%); recharge at ATMs (8%); and, ability to move value from a magnetic fare card to the Smart Card (7%).[95]

Multi-use Payment Systems

Benefits			
Goal Area	**# of Studies**	**Impact**	**Example**
Customer Satisfaction	1	+	Three projects in Europe demonstrated the coordinated use of a smart card as a payment system for public transit, shops, libraries, swimming pools, and/or other city services. User acceptance and satisfaction with these systems was very high, ranging from 71% - 87%.[51]

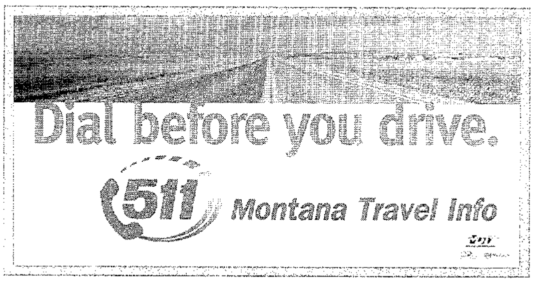
Costs		
Unit Costs Database	Transit Vehicle On-Board subsystem	See Appendix A
System Cost	No data to report.	

Impact Legend

- ++ substantial positive impacts
- \+ positive impacts
- ○ negligible impact
- +/– mixed results
- ? not enough data
- – negative impacts

2.7 Traveler Information

Providing traveler information on several modes of travel can be beneficial to both the traveler and service providers. Several transit agencies have started using traveler information websites to provide schedules, expected arrival times, expected trip times, and route planning services to patrons. See **www.transitweb.its.dot.gov** for a listing of, and access to, such sites. Also, many state DOT and local transportation agencies are providing current traffic conditions and expected travel times using similar approaches. Ongoing implementations of the designated 511 telephone number will improve access to traveler information. Each of these services allows users to make a more informed decision for trip departures, routes, and mode of travel, especially in bad weather. They have been shown to increase transit usage, and may help to reduce congestion when travelers choose to defer or postpone trips, or to select alternate routes. Information on impacts and costs of traveler information systems are separated into those which provide pre-trip information, and those that provide en route information, as shown in **Figure 2.7.1**.



Note that the traveler information programs discussed in this section of the report, and documented in the corresponding portions of the database, are generally regional, and occasionally multimodal in nature. Roadside or transit facility-based traveler information components such as DMS, HAR, and in-terminal displays are most often deployed, operated, and controlled by arterial, freeway, transit, or incident management systems. Earlier sections of this report discuss evaluations of these information dissemination technologies.

Evaluation of implemented traveler information systems reveals that the systems are well-received by those who make use of them. The number of travelers using the information generally represents a small portion of the total travelers in a region. Consequently, the evaluated systems have little, if any, impact on travel times across the regional transportation network. Nevertheless, individual users of the systems do perceive significant benefit from them and are generally satisfied with the service.

Tourism and event-related travel information focuses on the needs of travelers in areas unfamiliar to them or when traveling to events such as sporting activities or concerts. These services address issues of mobility and traveler convenience. Many of the tourism-related services are in the planning and development stages and few data regarding benefits for these services are available. Several national parks are

Intelligent Infrastructure

Traveler Information

- **Pre-trip Information**
  - Internet
  - 511
  - Other Telephone
  - TV/Radio
  - Kiosks
- **En Route Information**
  - 511
  - Other Telephone
  - Radio
  - In-Vehicle Systems (IVS)
- **Tourism & Events**
  - Travel Services
  - Advanced Parking
  - Electronic Payment

Figure 2.7.1
Taxonomy for Traveler Information

currently leading operational tests or are examining the possible impacts of these services. Information services could include electronic yellow pages, transit, and parking availability. The systems may also include mobility services such as pre-trip route selection or en route navigation.

For a summary of traveler information deployments across the U.S., refer to **www.itsdeployment.its.dot.gov**.

Table 2.7.1 provides information on the benefits and costs of traveler information systems. Information provided on the impacts of these systems is indicated using the symbols in the Impact Legend at the bottom corner of each page.

A case study in Washington, DC, simulated the experience of commuters with a need to be on time using a prospective pre-trip traveler information system during the months of August and September 1999. Overall, use of the advanced traveler information system (ATIS) proved advantageous in efficiently managing the traveler's time. Specific quantitative examples selected from the case study include:

- "Peak-period commuters who do not use ATIS were three to six times more likely to arrive late compared to counterparts who use ATIS;

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TABLE 2.7.1
BENEFITS AND COSTS OF TRAVELER INFORMATION

Pre-trip Information			
Benefits			
Goal Area	# of Studies	Impact	Example
Mobility	6	+	A simulation study of the Washington, DC, metropolitan area found that individuals using traveler information services could improve their on-time reliability while reducing the risk of running late. Individuals using traveler information improved their on-time reliability by 5 - 16 percentage points when compared to travelers not using the service.[96]
Capacity/ Throughput	4	○	Modeling studies in Detroit, Michigan, and Seattle, Washington, have shown slight improvements in corridor capacity with the provision of traveler information.[97,98]
Customer Satisfaction	14	++	While market penetration was low, 45% of San Francisco, California, travelers receiving information from the Travel Advisory Telephone System changed their travel plans and 81% of travelers receiving specific route information from the TravInfo Internet site changed their travel behavior. This compared to 25% of travelers altering their plans based on television or radio broadcasts.[99]
Energy/ Environment	1	?	A 1993 prospective study of traveler information in Boston, Massachusetts, found that the system would reduce vehicle emissions from participating travelers. The study estimated a 25% reduction in volatile organic compounds, a 1.5% reduction in oxides of nitrogen, and a 33% reduction in carbon monoxide.[100]

Chart continues on next page

Impact Legend
- ++ substantial positive impacts
- \+ positive impacts
- ○ negligible impact
- +/– mixed results
- ? not enough data
- – negative impacts

Costs		
Unit Costs Database	Information Service Provider subsystem Remote Location subsystem Transportation Management Center subsystem	See Appendix A
System Cost	The Arizona DOT enhanced its traveler information system, Trailmaster, as part of the AZTech MMDI project. The cost of the enhancement included hardware and software upgrades, and web page redesign. The project team estimated that the original Trailmaster website cost was approximately 10 times as much as that of the redesign.[57]	Cost: **$135,782** (1998) Annual O&M cost: **$116,551** (1998)
System Cost	Real-time traffic condition information similar to the information provided on the Trailmaster website (see above) is available at kiosks located at selected public and commercial sites. Approximately 28 kiosks are deployed in the Phoenix, Arizona, region.[57]	Project cost: **$459,732** (1998) Annual O&M cost: **$153,519** (1998)

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- Cases where ATIS clearly benefits the user (e.g., ATIS user on time, non-user late) outweighed cases where ATIS clearly disadvantages the user by five to one;
- ATIS users in peak periods are more frequently on time than conservative non-users, yet they experience only two-thirds as much early schedule delay as non-users;
- Late shock, the surprise of arriving late, is reduced by 81% through ATIS use."[96]

En-route Information

Benefits

Goal Area	# of Studies	Impact	Example
Mobility	4	+	Enhancements to the traveler information system in San Antonio, Texas, during the MMDI included improvements to the Internet website, and the installation of in-vehicle navigation (IVN) devices in vehicles operated by public agencies in the area. Modeling results indicate significant potential benefits for individuals using the devices. Over a one-year period, a traveler using an IVN device could experience an 8.1% reduction in delay.[19]
Customer Satisfaction	11	+	Surveys indicate that travelers generally find telephone traveler information systems to be useful. Several pilot studies have also investigated provision of traveler information via portable, or in-vehicle devices. These systems were well-received by drivers for public agencies in the San Antonio, Texas, area, particularly paratransit drivers and police investigators who are often requested to drive in unfamiliar areas.[19]

Costs		
Unit Costs Database	Roadside Telecommunications subsystem Roadside Information subsystem Transportation Management Center subsystem Vehicle On-Board subsystem Personal Devices subsystem	See Appendix A
System Cost	Nebraska's Department of Roads and the Nebraska State Patrol have teamed up to deploy a statewide 511 Traveler Information system. The new 511 system replaces the toll-free weather and road condition system formerly operated by the State Patrol.[24]	Initial cost: **$120,000** (2001) Estimated annual O&M cost: **$110,000** (2001)

Impact Legend
- ++ substantial positive impacts
- + positive impacts
- ○ negligible impact
- +/– mixed results
- ? not enough data
- – negative impacts

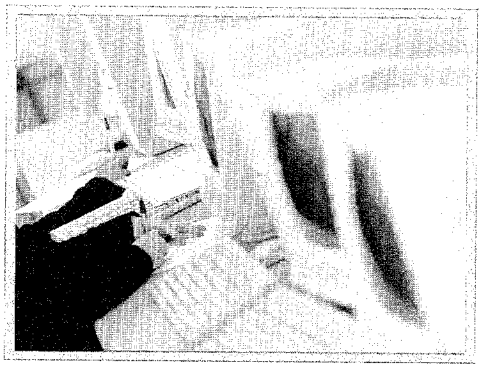
Tourism & Events			
Benefits			
Goal Area	**# of Studies**	**Impact**	**Example**
Customer Satisfaction	1	+	Surveys taken in popular vacationing destinations of Branson, Missouri, and along Interstate 40 in Arizona found that over 50% of travelers in the areas felt that information from the recently installed traveler information systems saved them time.[101]

Costs		
Unit Costs Database	Roadside Telecommunications subsystem Roadside Information subsystem Parking Management subsystem	See Appendix A
System Cost	The Seattle Center Advanced Parking Information System, in Seattle, Washington, provides information and routing directions to three major parking centers via dynamic message signs. This information is also available via the Internet, phone, and pagers to travelers prior to leaving for an event as well as travelers en route.[20]	System cost: **$925,265** (1998) Annual O&M cost: **$50,523** (1998)

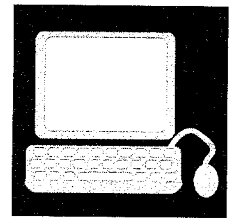
Impact Legend
- ++ substantial positive impacts
- + positive impacts
- ○ negligible impact
- +/– mixed results
- ? not enough data
- – negative impacts

2.8 INFORMATION MANAGEMENT

Data collected by ITS applications can be used to evaluate the historical performance of a transportation system using a variety of performance measures. In addition to supporting operational improvements, data collected by means of information management systems can assist in transportation planning, research, and safety management activities. The National ITS Program Plan released by the U.S. DOT in August 2000 has described the function of ITS data archiving as addressing "the collection, storage, and distribution of ITS data for transportation planning, administration, policy, operation, safety analyses, and research." The 1999 addition of the Archived Data User Service (ADUS) to the National ITS Architecture and subsequent program of federal activities to increase awareness of and professional capacity to implement Archived Data Management Systems (ADMS) underscores the value of retaining and analyzing data collected by ITS.



INTELLIGENT INFRASTRUCTURE



INFORMATION MANAGEMENT

Data Archiving

Figure 2.8.1
Taxonomy for Information Management

Figure 2.8.1 shows how data archiving applications fit into the ITS taxonomy. Operating agencies around the U.S. are in various stages of planning, implementing, and operating archived data management systems. As the performance of these systems is evaluated, examples of their effectiveness will become available.

For a summary of deployments of ADUS and ADMS across the U.S., refer to **www.itsdeployment.its.dot.gov**.

Table 2.8.1 provides available information on the costs of information management systems.

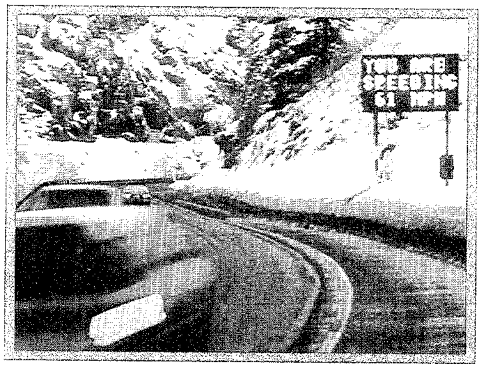
Table 2.8.1
Costs of Information Management

Data Archiving		
Benefits		
No data to report.		
Costs		
Unit Costs Database	No data to report.	
System Cost	The total cost of the Nevada DOT Freeway and Arterial System of Transportation (FAST) central system software design and development is approximately $4.225 million. The software will provide a fully automated freeway management system, plus the capability to receive, collect, archive, summarize, and distribute data generated by FAST. Of the $4.225 million, the cost to develop the design for the implementation of the Archived Data User Service (ADUS) for FAST was approximately $225,000. This cost included needs assessment, update of functional requirements, update of the regional architecture for the Las Vegas area, and system design.[11]	Software design and development cost: **$4.225** million (2001) ADUS design cost: **$225,000** (2001)

Impact Legend
- ++ substantial positive impacts
- \+ positive impacts
- o negligible impact
- +/– mixed results
- ? not enough data
- – negative impacts

2.9 Crash Prevention & Safety

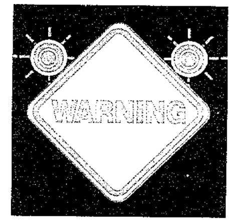
Information from crash prevention and safety applications can be used to implement roadway control strategies. A major goal of the ITS program is to improve safety and reduce risk for road users, including pedestrians, cyclists, operators, and occupants of all vehicles who must travel along a given roadway. **Figure 2.9.1** depicts the current classification for collecting crash prevention and safety systems benefits and costs information. Road geometry warning systems warn drivers, typically those in commercial trucks and other heavy vehicles, of potentially dangerous conditions which may cause rollovers or other crashes on ramps, curves, or downgrades. Highway-rail crossing systems can reduce the potential for catastrophic accidents involving school buses or hazardous materials. Over the last few years, the number of accidents occurring at highway-rail intersections has decreased; however, the goal of the Highway-Rail Intersection (HRI) User Service in the National Architecture is to further improve safety at these crossings, and improve coordination between rail operations and traffic management functions.



Intersection detection systems can reduce approach speeds at rural intersections by advising drivers of the presence and direction of approaching traffic. Pedestrian safety systems can help protect pedestrians by automatically activating in-pavement lighting to alert drivers as pedestrians enter crosswalks. Bicycle warning systems can notify drivers when a cyclist is in an upcoming stretch of roadway to improve safety on narrow bridges and tunnels. Animal warning systems have been deployed in Europe and are still being tested in the United States. These systems typically use radar to detect large animals approaching the roadway, and then alert drivers by activating flashers on warning signs located upstream of high-frequency crossing areas.

Table 2.9.1 provides information on the benefits and costs of crash prevention and safety systems. Information provided on the impacts of these systems is indicated using the symbols in the Impact Legend at the bottom corner of each page.

Intelligent Infrastructure



Crash Prevention & Safety

- **Road Geometry Warning Systems**
  - Ramp Rollover Warning
  - Curve Speed Warning
  - Downhill Speed Warning
  - Overheight/Overwidth Warning
- **Highway-Rail Crossing Systems**
- **Intersection Collision Warning**
- **Pedestrian Safety**
- **Bicycle Warning Systems**
- **Animal Warning Systems**

Figure 2.9.1
Taxonomy for Crash Prevention & Safety

Table 2.9.1
Benefits and Costs of Crash Prevention & Safety

Road Geometry Warning Systems: Ramp Rollover Warning			
Benefits			
Goal Area	# of Studies	Impact	Example
Safety	3	+	Ramp rollover warning systems were installed at three exit ramps on the Capital Beltway around Washington, DC. Two of the systems used sensor and weigh-in-motion scales to determine vehicle speed and weight classification, and one system only used vehicle speed measurements to calculate the probability of a truck rolling over. If a truck was in danger, a roadside warning sign was activated. Prior to deployment there were 10 truck rollover accidents at these sites between 1985 and 1990. After deployment, no accidents were recorded between 1993 and 1997.[25]

Costs		
Unit Costs Database	Roadside Detection subsystem Roadside Information subsystem Roadside Telecommunications subsystem	See Appendix A
System Cost	As mentioned in the benefits example above, three automatic ramp rollover warning systems have been deployed around the Washington, DC, Capital Beltway. The costs of this system consist of software, construction, calibration, commissioning, testing, and design.[103]	Single lane ramp cost: **$166,462** (1994) Dual lane ramp cost: **$268,507** (1994)

Road Geometry Warning Systems: Curve Speed Warning			
Benefits			
Goal Area	# of Studies	Impact	Example
Safety	1	?	An advanced curve warning system was installed on five curves along I-5 in a mountainous portion of rural northern California. A before-and-after evaluation at two sites showed a significant reduction in truck speeds on downgrades greater than 5%.[104]

Costs		
Unit Costs Database	Roadside Detection subsystem Roadside Information subsystem Roadside Telecommunications subsystem	See Appendix A
System Cost	No data to report.	

Impact Legend
- ++ substantial positive impacts
- + positive impacts
- ○ negligible impact
- +/– mixed results
- ? not enough data
- – negative impacts

Road Geometry Warning Systems: Downhill Speed Warning			
Benefits			
Goal Area	**# of Studies**	**Impact**	**Example**
Safety	3	+	A dynamic truck downhill speed warning system installed on I-70 in Colorado decreased truck accidents 13% and reduced the use of runway ramps 24%.[25]
Customer Satisfaction	1	?	A small-scale study of truck drivers who experienced the dynamic truck downhill speed warning system in Colorado indicated that most drivers thought it was helpful.[105]
Costs			
Unit Costs Database	Roadside Detection subsystem Roadside Information subsystem Roadside Telecommunications subsystem		See Appendix A
System Cost	A truck speed warning system was deployed on a downgrade curve along I-70 in Glenwood Canyon, Colorado. If a truck is detected (via radar) exceeding the posted speed, then the truck's speed is posted on a dynamic message sign. The system cost range is the estimated cost for a single site.[18]		System cost: **$25,000-$30,000** (1996)

Impact Legend
- ++ substantial positive impacts
- + positive impacts
- ○ negligible impact
- +/– mixed results
- ? not enough data
- – negative impacts

The ITS JPO at the US DOT evaluated seven projects that implemented ITS at highway-rail crossings. Among the seven projects five functions were tested:

- second train warning,
- four-quadrant gates,
- Intelligent Grade Crossing,
- in-vehicle warning, and
- crossing blockage information for traffic management and traveler information.

Second train warning systems were tested in Los Angeles, California, and Baltimore, Maryland. Each project entailed deployment of detection equipment and dynamic message signs at one crossing. Project costs were approximately $200,000 per project.

A four-quadrant gate with automatic train stop was deployed and tested in Groton, Connecticut. The system costs including equipment installed at the crossing and in-cab totaled $977,000.

A set of ITS technologies was deployed in Long Island, New York. The Intelligent Grade Crossing project included the following functions: constant warning time, transient gate control, emergency vehicle priority,

continued on next page

Highway Rail Crossing Systems

Benefits

Goal Area	# of Studies	Impact	Example
Safety	3	+	In San Antonio, Texas, simulations of increased traffic volume showed that DMS with railroad crossing delay information may decrease crashes by 9%.[19]
Mobility	2	?	The San Antonio, Texas, simulations of increased traffic volumes indicated DMS with railroad crossing delay information may decrease system delay by 7%.[19]
Customer Satisfaction	1	?	Before implementation of an automated warning system, 77% of surveyed residents in Ames, Iowa, indicated that train horns had a "negative" or "very negative" impact on their quality of life. After deployment, 82% of residents responded that the automated horn was "no problem."[106]
Energy/ Environment	2	?	Noise levels were measured at a highway-rail intersection before and after installation of the automated horn system in Ames, Iowa. Results indicated that areas impacted by noise levels greater than 80 decibels decreased by 97%.[106]

Costs

Unit Costs Database	Roadside Rail Crossing subsystem Roadside Detection subsystem Roadside Information subsystem Roadside Telecommunications subsystem	See Appendix A
System Cost	The Advanced Warning for Railroad Delays (AWARD) project was implemented as part of the San Antonio, Texas, MMDI. The project consisted of Doppler radar and acoustic sensors deployed at selected locations of railroad tracks to detect the presence, speed, and length of oncoming trains as they approach grade crossings. Data are transmitted to the TransGuide Operations Center where the data are analyzed and railroad delay information is communicated to travelers on existing dynamic message signs.[19]	Capital cost: **$350,800** (1998) Annual O&M cost: **$34,000** (1998)

Impact Legend

- ++ substantial positive impacts
- + positive impacts
- ○ negligible impact
- +/– mixed results
- ? not enough data
- – negative impacts

Intersection Collision Warning

Benefits			
Goal Area	# of Studies	Impact	Example
Safety	1	?	A Collision Countermeasure System (CCS) was installed at an unsignalized, two-way, stop-controlled intersection in a rural area of Aden, Virginia. Before-and-after field data indicated the system lowered approach speeds. Safer projected-times-to-collision (PTCs) were observed after system implementation.[108]

Costs		
Unit Costs Database	No data to report.	See Appendix A
System Cost	No data to report.	

Pedestrian Safety

Benefits
No data to report.

Costs		
Unit Costs Database	Roadside Detection subsystem Roadside Information subsystem Roadside Telecommunications subsystem	See Appendix A
System Cost	A downtown Boulder, Colorado, intersection has been equipped with a series of four flashing in-pavement lights per lane. This high pedestrian-volume intersection is also equipped with two flashing pedestrian signs. The lights and signs are activated manually. Project cost includes equipment and installation costs.[18]	Project cost: **$8,000-$16,000**

continued from last page

minimization of gate down-times, dynamic message signs, stalled automobile detection, and queued vehicle detection. The comprehensive technologies deployed are reflected in the approximately $9.5 million project cost.

Two projects involved deployment of in-vehicle warning systems. The northern Chicago, Illinois, project included 5 crossings and 300 vehicles at a cost of approximately $700,000. The Glencoe, Minnesota, project involved 5 crossings and 30 vehicles at a total cost of approximately $1 million.

Detection devices were deployed in San Antonio, Texas, to detect oncoming trains, their length, and speed. Data were analyzed and used for traffic management as well as informing travelers of possible delays. Project cost was approximately $440,000.[107] (Note: This project cost for AWARD differs slightly from that reported by Carter, et al. The difference reflects an increase in the number of sensors included in this reference and the inclusion of miscellaneous private sector expenses not included in Carter, et al.)

Impact Legend
- ++ substantial positive impacts
- \+ positive impacts
- o negligible impact
- +/– mixed results
- ? not enough data
- – negative impacts

Bicycle Warning Systems

Benefits

No data to report.

Costs

Unit Costs Database	No data to report.	See Appendix A
System Cost	A Bicycle in Tunnel Warning System was deployed at a tunnel on Highway 971 near Chelan, Washington. Flashing beacons on a fixed message sign are activated when a cyclist presses a push-button, and deactivate after a preset time interval has passed. The fixed message sign reads, "PEDS/BICYCLES IN TUNNEL WHEN FLASHING." The cost to implement the system was kept low due to the existing power source at the tunnel entrance.[18]	System cost: **$5,000** (1979)

Animal Warning Systems

Benefits

No data to report.

Costs

Unit Costs Database	No data to report.	
System Cost	An Animal Warning System has been deployed in the Greater Yellowstone Rural Intelligent Transportation Systems (GYRITS) corridor. A transmitter is installed along the road where a high number of animal-vehicle incidents have occurred. The cost per site includes transmitter, solar pack, and installation (estimated). The cost does not include off-the-shelf in-vehicle radar detectors required to receive the signal from the transmitter.[18]	System cost: **$3,800** per site

Impact Legend
- ++ substantial positive impacts
- + positive impacts
- 0 negligible impact
- +/- mixed results
- ? not enough data
- – negative impacts

2.10 Roadway Operations & Maintenance

Operating and maintaining transportation systems is costly. Many state DOTs are implementing ITS to better manage roadway maintenance efforts and to enhance safety on the transportation system. ITS applications in operations and maintenance focus on integrated management of maintenance fleets, specialized service vehicles, hazardous road conditions remediation, and work zone mobility and safety. Systems and processes are required to monitor, analyze, and disseminate roadway/infrastructure data for operational, maintenance, and managerial uses. ITS can help secure the safety of workers and travelers in a work zone while facilitating traffic flow through and around the construction area.

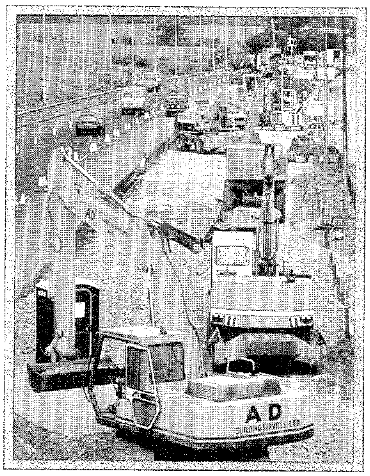
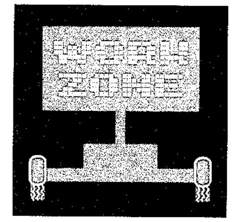


Figure 2.10.1 summarizes the classification scheme for collecting benefits and cost information for roadway operation and maintenance. Information dissemination technologies can be deployed temporarily, or the existing systems can be updated periodically to provide information on work zones or other highway maintenance activities. Several applications help state DOTs with asset management, including fleet tracking applications, as well as automated data collection applications for monitoring the condition of highway infrastructure. Applications in work zones include the temporary implementation of traffic management or incident management capabilities. These temporary systems can be stand-alone implementations, or they may supplement existing systems in the area during construction. Other applications for managing work zones include measures to control vehicle speeds and notify travelers of changes in lane configurations or travel times and delays through the work zones.

Winter weather maintenance applications fall under Road Weather Management, discussed in Section 2.11.

Table 2.10.1 provides information on the benefits and costs of ITS applications in roadway operations and maintenance. Information provided on the impacts of these systems is indicated using the symbols in the Impact Legend at the bottom corner of each page.

INTELLIGENT INFRASTRUCTURE



ROADWAY OPERATIONS & MAINTENANCE

- **Information Dissemination**
  - Portable DMS
  - HAR
  - Internet/Wireless/Phone
- **Asset Management**
  - Fleet Management
  - Infrastructure Management
- **Work Zone Management**
  - Temporary Traffic Management
  - Temporary Incident Management
  - Lane Control
  - Variable Speed Limit
  - Speed Enforcement
  - Intrusion Detection

Figure 2.10.1
Taxonomy for Roadway Operations & Maintenance

Table 2.10.1
Benefits and Costs of Roadway Operations & Maintenance

The purpose of the Advanced Rural Transpor - tation Information and Coordination (ARTIC) project in Minnesota is to share application of ITS across various public agencies such as transportation, public safety, and transit utilizing a central communi-cations center. GPS equipment was installed on fleet vehicles (i.e., plows, buses, volunteer, and trooper vehicles) for ease of location, identification, and dispatching. Mobile data terminals (MDTs) were also installed allowing for data transmission between the vehicles and the dispatch center. The project costs are estimated at $1.574 million.[18]

Information Dissemination		
Benefits		
No data to report.		
Costs		
Unit Costs Database	Roadside Information subsystem Roadside Telecommunications subsystem	See Appendix A
System Cost	Dane County, Wisconsin, uses portable dynamic message signs to notify motorists of upcoming construction and maintenance projects or of alternate routes. Power can be provided via solar pack or battery.[18]	Cost: **$25,000** per sign

Asset Management: Fleet Management		
Benefits		
No data to report.		
Costs		
Unit Costs Database	Fleet Management subsystem	See Appendix A
System Cost	A pen-based hand-held computer is used by the Indiana DOT to facilitate fleet vehicle inspections. Fleet vehicle information can be entered and retrieved from the tracking system.[18]	Hand-held computer cost: **$500** (approx.) (1997)

Asset Management: Infrastructure Management		
Benefits		
No data to report.		
Costs		
Unit Costs Database	Fleet Management subsystem	See Appendix A
System Cost	No data to report.	

Impact Legend
- ++ substantial positive impacts
- \+ positive impacts
- o negligible impact
- +/- mixed results
- ? not enough data
- – negative impacts

Work Zone Management

Benefits

Goal Area	# of Studies	Impact	Example
Mobility	1	+	Average clearance times for incidents were reduced 44% with the implementation of motorist assistance patrols and a temporary traffic management center during a construction project at the "Big I" interchange in Albuquerque, New Mexico. Two courtesy patrols and one wrecker were on duty during weekdays, and a police substation was operational at the work zone during A.M. and P.M. peak periods.[26]
Customer Satisfaction	1	?	An investigation into remote speed enforcement in work zones in Texas drew mixed results from project participants. While officers felt the system had the potential to allow safe enforcement of speed limits in work zones, by relaying images of offending drivers to officers downstream, some had concerns regarding the proper identification of speeding vehicles.[109]

Costs

Unit Costs Database	Roadside Detection subsystem Roadside Control subsystem	See Appendix A
System Cost	Ohio DOT installed web cameras in its I-70 work zone to assist in traffic management. The cost of installation was kept very low due to the use of temporary structures. Although the installations were temporary and would not meet environmental standards for permanent structures, the video images of traffic in the construction areas were beneficial to Ohio DOT.[110]	System cost: **$17,000** for eight cameras
System Cost	Michigan DOT teamed up with FHWA and Michigan State University for an 18-month study to test the use of variable speed limits (VSL) in work zones. The equipment, 7 VSL trailers, was rented for the study. The project cost includes the equipment, technical support, and transport of the VSL trailers.[27]	Project cost: **$400,900** (2002)

Impact Legend

- ++ substantial positive impacts
- + positive impacts
- o negligible impact
- +/– mixed results
- ? not enough data
- – negative impacts

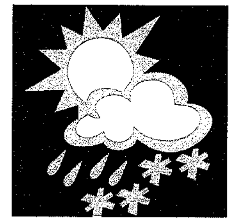
2.11 Road Weather Management

Adverse weather conditions pose a significant threat to the infrastructure and operation of our nation's roads. The Road Weather Management Program was created to coordinate several weather-related activities in the Federal Highway Administration. The program focuses on development of improved road weather information systems (RWIS), development of improved winter maintenance technologies, and coordination of operations within and between state DOTs.

Figure 2.11.1 depicts the classification of benefit and cost data associated with Road Weather Management.

Table 2.11.1 provides information on the benefits and costs of road weather management systems. Information provided on the impacts of these systems is indicated using the symbols in the Impact Legend at the bottom corner of each page.

INTELLIGENT INFRASTRUCTURE



ROAD WEATHER MANAGEMENT

- **Surveillance, Monitoring, & Prediction**
  - Road Surface
  - Atmospheric Conditions
- **Information Dissemination**
  - Dynamic Message Signs (DMS)
  - Internet/Wireless/Phone
  - Highway Advisory Radio (HAR)
- **Traffic Control**
  - Variable Speed Limits
  - Signals
  - Lane Use
- **Response & Treatment**
  - Fixed Winter Maintenance
  - Mobile Winter Maintenance

Figure 2.11.1
Taxonomy for Road Weather Management

TABLE 2.11.1
BENEFITS AND COSTS OF ROAD WEATHER MANAGEMENT

Surveillance, Monitoring, & Prediction

Benefits

No data to report.

Costs

Unit Costs Database	Roadside Detection subsystem Transportation Management subsystem Roadside Telecommunications subsystem	See Appendix A
System Cost	Texas DOT implemented a Road Weather Information System (RWIS) in Abilene, Texas. The RWIS includes roadside surface and atmospheric sensors, remote processing units, and a central processing unit with road weather software. The annual O&M cost is based on the average maintenance contract per roadside (remote) site. One central unit can support multiple remote sensing sites.[111]	System cost: **$42,000** (1997) Annual O&M cost: **$5,460** per remote site (1997)

Information Dissemination

Benefits

Goal Area	# of Studies	Impact	Example
Safety	6	+	An Idaho DOT study found significant speed reductions when weather-related warnings were posted on dynamic message signs. During periods of high winds and snow covered pavement, vehicle speeds dropped 35% to 35 mph when warning messages were displayed, compared to a 9% drop to 44 mph without the dynamic message signs.[28]

Costs

Unit Costs Database	Roadside Telecommunications subsystem Roadside Information subsystem	See Appendix A
System Cost	Washington State DOT has implemented three highway advisory radios along the Blewett/Stevens Pass to provide weather and road condition information to travelers and maintenance crews. Annual O&M costs based on prior experience to operate and maintain.[11]	Average cost of equipment (including installation): **$20,000** (2001) Annual O&M cost: **$1,000** (2001)
System Cost	Nebraska's Department of Roads and the Nebraska State Patrol have teamed up to deploy a statewide 511 Traveler Information system. The new 511 system replaces the toll-free weather and road condition system formerly operated by the State Patrol.[24]	Initial cost: **$120,000** (2001) Estimated annual O&M cost: **$110,000** (2001)

To address weather-related accidents on a section of I-90 near Vantage, Washington, the Washington State DOT assessed the benefits and costs of deploying an automated anti-icing system to prevent the formation of pavement frost and black ice and to reduce the impact of freezing rain. Poor road surface conditions contribute to 42 percent of total accidents and 70 percent of winter accidents. The high-accident corridor includes a 955-foot radius horizontal curve and a vertical alignment transition from three to five percent within the limits of the curve.

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Impact Legend
- ++ substantial positive impacts
- \+ positive impacts
- ○ negligible impact
- +/– mixed results
- ? not enough data
- – negative impacts

Traffic Control

Benefits			
Goal Area	# of Studies	Impact	Example
Safety	5	+	A variable speed limit system implemented in the Netherlands to control traffic during foggy conditions was found to reduce average speeds 8 to 10 kph, with a slight decrease in speed variability.[112]
Mobility	1	○	An investigative study sponsored by the Minnesota Department of Transportation found that optimizing traffic signals along an arterial corridor to accommodate adverse winter weather conditions yielded an 8% reduction in delay. The study also noted that the existing signal timing plans were sufficient to accommodate the lower traffic volumes and lower speeds during winter weather.[113]
Customer Satisfaction	1	?	Survey results in Finland indicate that 90% of drivers found weather-controlled variable speed limit signs to be useful.[114]
Productivity	2	+	The Mn/DOT uses mainline and ramp closure gates to close segments of freeways during severe weather. During a 1998 storm, closure allowed Interstate 90 to be cleared 4 hours earlier than nearby Highway 75, with I-90 clearance costs 18% lower than those for Highway 75.[115]

Costs		
Unit Costs Database	Roadside Control subsystem Roadside Detection subsystem Roadside Information subsystem	See Appendix A
System Cost	Washington State DOT implemented Travel Aid, a variable speed limit (VSL) system that changes as the weather does, along the Snoqualmie Pass (I-90) east of Seattle. Approximately 13 miles are operated as VSL during the winter months. The system consists of radar detection, six weather stations, nine dynamic message signs, and radio and microwave transmission systems.[18, 71, 72]	Design and implementation cost: $5 million (1997)

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The proposed installation consists of a liquid chemical storage tank, a pump, a dispensing system with spray nozzles, an environmental sensor station (ESS), a computerized control system, and a closed circuit television (CCTV) camera for remote viewing. The initial cost estimate was $599,500. The control system monitors weather and road condition data from the ESS, and automatically activates the dispensing system when predetermined conditions exist. The system also alerts dispatchers and the maintenance supervisor when the anti-icing system is activated. Annual O&M costs were estimated at $32,800.

The present worth of costs, the present worth of benefits, and the benefit/cost (B/C) ratio were calculated with WSDOT's Benefit/Cost Worksheet for Collision Reduction. Cost elements included design, construction, power and communication, and operations and maintenance costs. Benefits were the estimated reduction in snow, ice, and wet pavement

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Impact Legend
- ++ substantial positive impacts
- + positive impacts
- ○ negligible impact
- +/– mixed results
- ? not enough data
- – negative impacts

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accidents. Using historical accident data, the annual rate of collisions over a three-year period was determined and compared to the expected rate of collisions after system implementation. It was presumed that 80 percent of the snow, ice, and wet pavement accidents would be eliminated. The cost per collision was used to determine the annual safety benefit. The analysis resulted in a B/C ratio of 2.36 with a net benefit of $1,179,274. In addition to cost savings from accident reductions, WSDOT management expects that abrasives usage will be significantly reduced, resulting in lower cleanup costs and less damage to drainage structures. Improved level of service should also result from the deployment, enhancing mobility.

Initially, it was assumed that 60 percent of snow and ice accidents would be eliminated by the proposed system, with no reduction in wet-pavement accidents. Based upon discussions with Pennsylvania DOT maintenance managers, this assumption was revised to 80 percent of snow and ice accidents.[119] (1999)

Response & Treatment

Benefits

Goal Area	# of Studies	Impact	Example
Safety	3	?	The Finnish National Road Administration estimates that the duration of slippery road conditions has been reduced 10 - 30 minutes per de-icing activity with improvements to winter maintenance enabled by the implementation of an extensive road weather information system.[116]
Productivity	6	+	The Wisconsin DOT has found that a snow forecasting model combined with ice detection systems helps improve planning for work schedules, reducing labor-hours up to 4 hours per person during a significant storm.[117]

Costs

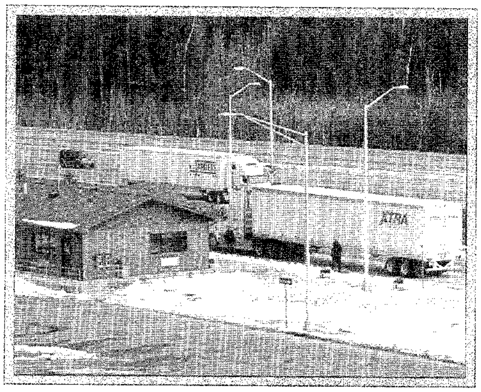
Unit Costs Database	Roadside Control subsystem Roadside Telecommunicatons subsystem	See Appendix A
System Cost	The Minnesota DOT installed an automatic bridge de-icing system on TH61 at Dresbach, Minnesota. The system consists of bridge and bridge approach spray equipment and a 200-gallon tank and shelter. The system can be activated manually or remotely via phone line. The expected lifetime of the system is 12 years.[118]	System cost: **$25,000** (1998) Annual O&M cost: **$2,000** (1998)
System Cost	The Southeast Michigan Snow and Ice Management (SEMSIM) project is a multi-agency AVL system in which 500 highway maintenance vehicles are to be equipped with GPS receivers and sensors to monitor snow plow use, rate of application for de-icing materials, and air and road temperature. Data are transmitted via 900 MHz to a central system.[11]	AVL/GPS system cost: **$1.862** million (estimated) (2002)

Impact Legend

- ++ substantial positive impacts
- + positive impacts
- o negligible impact
- +/– mixed results
- ? not enough data
- – negative impacts

2.12 Commercial Vehicle Operations

ITS applications for commercial vehicle operations are designed to enhance communication between motor carriers and regulatory agencies, particularly during interstate freight movements. ITS can aid both carriers and agencies in reducing operating expenses through increased efficiency, and assist in ensuring the safety of motor carriers operating on the nation's roadways. Carriers will move quickly to equip their own fleets with systems that will improve efficiency, safety, or other measures that provide them with a competitive advantage. **Figure 2.12.1** shows the components of the ITS taxonomy for commercial vehicle operations.



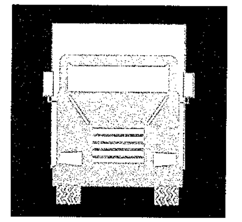
Credentials administration applications support administrative functions and provide savings to state and administrative agencies. Electronic registration and permitting can improve the time required for states to approve permits. Third-party clearinghouses can facilitate the exchange of credentials data between agencies and jurisdictions, and various electronic data exchange methods can facilitate business between agencies and carriers.

Several applications are intended to help assure the safety of motor carrier operations. Improved safety information exchange programs assist the safe operation of commercial vehicles, providing inspectors with better access to carrier and vehicle safety information. This allows a greater number of unsafe commercial vehicles and drivers to be removed from the roadway.

Recently, the Commercial Vehicle Information Systems and Networks (CVISN) program implemented safety information exchange in a number of prototype states. In addition, automated inspection equipment has been implemented to remotely test commercial trucks for faulty equipment. Authorities are able to investigate a larger portion of potentially unsafe vehicles through more efficient targeting.

Electronic screening of commercial vehicles can reduce congestion at inspection stations, improve travel time for commercial vehicles, and help operating companies and regulating agencies reduce costs. In-vehicle transponders can communicate with weigh stations and customs checkpoints to pre-screen trucks for safety records, border clearance, and proper credentials. Weigh-in-motion (WIM) scales can be used for more efficient weight screening. These technologies can reduce congestion at inspection stations by allowing safe and legal carriers to bypass weight and safety inspections and return to the mainline without stopping.

INTELLIGENT INFRASTRUCTURE



COMMERCIAL VEHICLE OPERATIONS

- **Credentials Administration**
  - Electronic Funds
  - Electronic Registration/ Permitting
- **Safety Assurance**
  - Safety Information Exchange
  - Automated Inspection
- **Electronic Screening**
  - Safety Screening
  - Border Clearance
  - Weight Screening
  - Credential Checking
- **Carrier Operations & Fleet Management**
  - AVL/CAD
  - On-Board Monitoring
  - Traveler Information
- **Security Operations**
  - Asset Tracking
  - Remote Disabling Systems

Figure 2.12.1
Taxonomy for Commercial Vehicle Operations

Several technologies are available to assist motor carriers with their day-to-day operations. AVL/CAD can assist with scheduling and tracking of vehicle loads, on-board monitoring of cargo can alert drivers and carriers of potential unsafe load conditions, and targeted traveler information can help carriers choose alternate departure times, avoid traffic, and arrive on time.

ITS can also be used to ensure the security of motor carriers. Asset tracking can improve the safety and security of drivers and vehicles by installing technologies that can monitor the location and condition of fleet assets (e.g., trailers, cabs, and trucks) in real time. Remote disabling systems can be installed to prevent unauthorized operation and assist in asset recovery.

Table 2.12.1 provides information on the benefits and costs of ITS for commercial vehicle operations. Information provided on the impacts of these systems is indicated using the symbols in the Impact Legend at the bottom corner of each page.

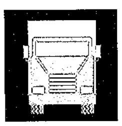


TABLE 2.12.1
BENEFITS AND COSTS OF ITS FOR COMMERCIAL VEHICLE OPERATIONS

Credentials Administration: Electronic Funds			
Benefits			
Goal Area	**# of Studies**	**Impact**	**Example**
Customer Satisfaction	1	?	A survey of members of the Maryland Motor Truck Association (MMTA) and the Independent Truckers and Drivers Association (ITDA) indicated the potential value of Electronic Data Interchange (EDI) and the Internet for conducting business with Maryland state agencies rated 1.85 and 2.04 on a scale of one to three.[120]
Productivity	1	?	A two-year study by the American Trucking Associations Foundation found that the commercial vehicle administrative processes (CVAP) reduced carriers' costs by an estimated 9 - 18% when electronic data interchange (EDI) was used.[121]
Costs			
Unit Costs Database	No data to report.		
System Cost	No data to report.		

Impact Legend
- ++ substantial positive impacts
- \+ positive impacts
- o negligible impact
- +/- mixed results
- ? not enough data
- – negative impacts

Credentials Administration: Electronic Registration/Permits			
Benefits			
Goal Area	**# of Studies**	**Impact**	**Example**
Mobility	2	+	In Europe, several projects investigated management systems designed to improve the operating efficiency of carriers. Benefits included a 30% reduction in order processing time and fewer processing errors.[51]
Customer Satisfaction	2	?	In a survey of Maryland Motor Truck Association members, 33% felt electronic registration was valuable, 13% were neutral, and 11% thought it had little or no value; 43% were unable to comment.[120]
Productivity	5	++	Three motor carriers surveyed during the CVISN model deployment initiative indicated that electronic credentialing reduced paperwork and saved them 60 - 75% on credentialing costs. In addition, motor carriers were able to commission new vehicles 60% faster by printing their own credential paperwork and not waiting for conventional mail delivery.[29]
Costs			
Unit Costs Database	Commercial Vehicle Administration subsystem Fleet Management Center subsystem		See Appendix A
System Cost	Kentucky and Maryland have implemented end-to-end International Registration Plan (IRP) electronic credentialing systems within their states. The costs to deploy these systems vary with the unique characteristics of each state. A significant impact on cost is whether commercial software is used or special software is developed and if third-party services will be used.[29]		End-to-end IRP cost incurred by the state: **$464,802-$935,906**

Impact Legend

- ++ substantial positive impacts
- \+ positive impacts
- ○ negligible impact
- +/– mixed results
- ? not enough data
- – negative impacts

2.12 Commercial Vehicle Operations

Safety Assurance: Safety Information Exchange

Benefits			
Goal Area	**# of Studies**	**Impact**	**Example**
Safety	1	?	The results of field testing in Connecticut indicate that Inspection Selection Systems (ISS) supplemented with electronic sharing of safety inspection data increased out-of-service order rates by 2%. Modeling efforts estimated that ISS could prevent 84 commercial vehicle accidents per year nationwide.[29]

Costs		
Unit Costs Database	Commercial Vehicle Administration subsystem Commercial Vehicle Check Station subsystem	See Appendix A
System Cost	Using cost data based on full CVISN deployment of Safety Information Exchange (SIE) systems in Kentucky and Connecticut, an estimate can be calculated for other states. Initial SIE systems include wireless telecommunications, Safety and Fitness Electronic Record (SAFER) Data Mailbox, and Commercial Vehicle Information Exchange Window (CVIEW). System cost assumes a state has 50 mobile enforcement units.[29]	System cost: **$650,000** Estimated annual O&M cost: **$161,000**

Safety Assurance: Automated Inspection

Benefits			
Goal Area	**# of Studies**	**Impact**	**Example**
Customer Satisfaction	1	?	In a survey of truck and motorcoach drivers, participants were asked about the utility of various ITS applications in commercial vehicles. Truck drivers held much less favorable opinions of automated roadside safety inspection than motorcoach drivers.[122]
Safety	1	+	Four states (Georgia, Kentucky, North Carolina, and Tennessee) participated in a year-long test to evaluate the performance of an infrared brake screening system designed to inspect commercial vehicles for brake problems as they enter weigh stations. The percentage of commercial vehicles placed out of service because of brake problems increased by a factor of 2.5 as a result of infrared screening at these stations.[123]

Costs	
Unit Costs Database	No data to report.
System Cost	No data to report.

Impact Legend
- ++ substantial positive impacts
- + positive impacts
- ○ negligible impact
- +/− mixed results
- ? not enough data
- − negative impacts

Electronic Screening: Safety Screening

Benefits			
Goal Area	# of Studies	Impact	Example
Mobility	1	?	Most truck drivers and CVO inspectors surveyed during the CVISN MDI felt electronic screening saved them time.[29]
Customer Satisfaction	1	+/–	Motor carriers surveyed during the CVISN MDI were concerned with the cost-effectiveness of electronic screening methods and the expansion of state regulation. However, most truck drivers felt that electronic screening saved them time. Inspectors also noted that CVISN saved time and improved the accuracy and speed of data reporting.[29]
Productivity	2	?	The CVISN MDI analysis considered start-up costs, operating costs, and crash avoidance from better targeted screening over the expected lifetime of the technology. Without considering the cost-saving benefits of crash avoidance from increased motor carrier compliance, the study estimated that electronic screening would have a B/C ratio of 2:1.[29]

Costs		
Unit Costs Database	Commercial Vehicle Check Station subsystem Commercial Vehicle On-Board subsystem	See Appendix A
System Cost	No data to report.	

Electronic Screening: Border Clearance

Benefits			
Goal Area	# of Studies	Impact	Example
Mobility	3	+	Simulation models of traffic on the Ambassador Bridge Border Crossing System (ABBCS) showed that electronic border clearance could save equipped trucks 50% of the delay through customs.[124]

Costs	
Unit Costs Database	No data to report.
System Cost	No data to report.

Impact Legend
- ++ substantial positive impacts
- \+ positive impacts
- o negligible impact
- +/– mixed results
- ? not enough data
- – negative impacts

2.12 Commercial Vehicle Operations

New York was one of five states selected to receive funding through the I-95 Corridor Coalition to develop electronic credentialing systems that would provide a more cost-effective method for commercial vehicle registration and data exchange between states, carriers, and third-party clearinghouses. Four of the states originally selected to participate in the evaluation were unable to complete the program due to the lack of available technical resources. New York developed an Internet-based electronic credentialing system, One-Stop-Credentialing and Registration (OSCAR), as a proof-of-concept demonstration. OSCAR provides the following functions:

- Credential application forms accessible via the Internet
- International Registration Plan (IRP) credentialing
- International Fuel Tax Agreement (IFTA) credentialing
- Highway User Tax (HUT) credentialing
- Single State Registration System (SSRS) credentialing

continued on next page

Electronic Screening: Weight Screening

Benefits

Goal Area	# of Studies	Impact	Example
Mobility	1	?	The Westa (weigh station) simulation model evaluated weigh station throughput in Seymour, Indiana, based on variations in entrance ramp length, deployment of screening transponders, and use of weigh-in-motion (WIM) scales. The model showed that WIM scales can be very effective at reducing the number of trucks in queue at weigh stations.[125]

Costs

Unit Costs Database	No data to report.
System Cost	No data to report.

Electronic Screening: Credential Checking

Benefits

Goal Area	# of Studies	Impact	Example
Customer Satisfaction	1	?	Drivers of trucks and motorcoaches were asked about the utility of various ITS applications in commercial vehicles. Both motorcoach and truck drivers held favorable opinions of Commercial Vehicle Electronic Clearance.[122]
Productivity	2	?	A survey of the mid-continent transportation corridor along Interstate Highway (IH) 35 from Duluth, Minnesota, to Laredo, Texas, showed that except for the most conservative growth and high-cost estimates, benefits of electronic credential checking exceed costs for most motor carriers. State agencies, however, were able to realize positive B/C ratios only when very aggressive growth scenarios were paired with low-cost estimates.[126]

Costs

Unit Costs Database	Commercial Vehicle Check Station subsystem Commercial Vehicle On-Board subsystem	See Appendix A
System Cost	Electronic screening infrastructure typically includes automatic vehicle identification (AVI), weigh-in-motion (WIM) scales, signage, workstations, and telecommunications at the roadside, and transponders installed in commercial vehicles. The majority of the cost for electronic screening is borne by state agencies. Electronic screening costs can range broadly depending on the level of infrastructure.[29, 126, 127]	Roadside equipment cost range: **$150,000-$780,000** In-vehicle transponder cost: **$50**
System Cost	States interested in converting existing static weigh stations to participate in CVISN electronic screening would not incur some of the one-time start-up costs for the initial site such as software development.[29]	Cost for first site: **$522,252** Cost for additional site: **$303,450**

Impact Legend

- ++ substantial positive impacts
- \+ positive impacts
- ○ negligible impact
- +/- mixed results
- ? not enough data
- − negative impacts

Carrier Operations & Fleet Management: AVL/CAD

Benefits

Goal Area	# of Studies	Impact	Example
Mobility	1	?	In Europe, several projects investigated management systems designed to improve the operating efficiency of carriers. Centralized route planning systems reduced vehicle travel distances 18% and decreased travel time 14%.[51]
Productivity	2	+	A survey conducted by the American Trucking Association Foundation found that CAD systems increased productivity 5 - 15% by increasing the number of pickups and deliveries per truck per day.[128]

Costs

Unit Costs Database	Fleet Management Center subsystem Commercial Vehicle On-Board subsystem	See Appendix A
System Cost	A tracking device installed on fleet trailers can integrate GPS technology with the Internet to provide a secure cost-effective method for remote and accurate management of trailers. The self-powered unit has a rechargeable battery pack, a roof-mounted combination GPS and wireless antenna, and a roof-mounted solar panel.[31]	Cost: beginning at **$800** per trailer (2000) Monthly service cost: **$19** per subscriber with a 3-year contract (2000)

continued from last page

The total project cost was $577,910. Equipment (including servers, computers, and printers) and database software were estimated to cost $133,750. Software development, which accounted for the largest cost item of the project, including testing, was $429,760. The cost for end-user support and training was $14,400.[131] (1997)

Carrier Operations & Fleet Management: On-Board Monitoring

Benefits

Goal Area	# of Studies	Impact	Example
Productivity	2	–	The American Trucking Association Foundation (ATAF) conducted an extensive benefit/cost analysis of the effects of CVO user services on regulatory compliance cost of motor carriers. The benefit/cost ratio for on-board safety monitoring ranged from 0.49:1 to 0.02:1.[129]

Costs

Unit Costs Database	No data to report.
System Cost	No data to report.

Impact Legend

- ++ substantial positive impacts
- \+ positive impacts
- o negligible impact
- +/– mixed results
- ? not enough data
- – negative impacts

2.12 Commercial Vehicle Operations

Carrier Operations & Fleet Management: Traveler Information			
Benefits			
Goal Area	# of Studies	Impact	Example
Customer Satisfaction	1	?	The FleetForward operational test conducted by the ATAF provided commercial truckers with real-time traffic information to facilitate routing decisions and improve the operational efficiencies of motor carrier operations along the eastern corridor. Although operating efficiencies were not significantly impacted, 75% of motor carriers felt traffic information was a valuable tool for identifying congestion.[130]
Costs			
Unit Costs Database	No data to report.		
System Cost	No data to report.		

Impact Legend
- ++ substantial positive impacts
- + positive impacts
- ○ negligible impact
- +/– mixed results
- ? not enough data
- – negative impacts

2.13 Intermodal Freight

ITS can facilitate the safe, efficient, secure, and seamless movement of freight. **Figure 2.13.1** shows how intermodal freight applications fit into the ITS taxonomy. Freight tracking applications can monitor, detect, and communicate freight status information to ensure containers remain sealed while en route. In addition, asset tracking technologies can monitor the location and identity of containers in real-time. ITS freight terminal processes can improve the efficiency of freight transfers by activating transponder tags to track cargo containers within the terminal as they are processed and sealed for transfer. ITS drayage operations can promote the efficient loading, unloading, sorting, and transfer of cargo by implementing automated systems and robotics to optimize limited dock and port space. At international border crossings, automating revenue transactions and faster, more efficient confirmation of cargo manifest information can reduce delays associated with customs and tax collection processing. In addition, ITS applications that optimize traffic control and coordinate transfers near intermodal ports of entry can help reduce the strain of increased freight movement on the nation's freight highway connector system.

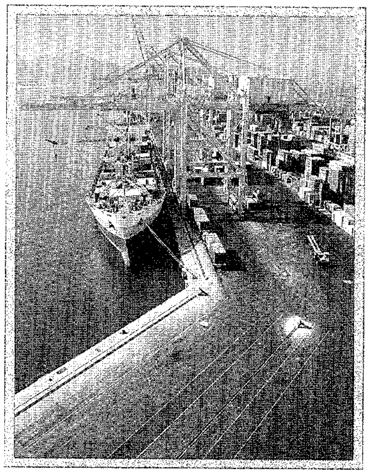
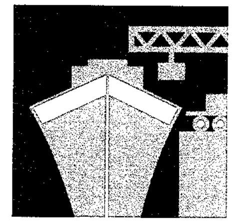


Table 2.13.1 provides information on the benefits and costs of intermodal freight ITS. Information provided on the impacts of these systems is indicated using the symbols in the Impact Legend at the bottom corner of the following pages.

INTELLIGENT INFRASTRUCTURE



INTERMODAL FREIGHT

- Freight Tracking
- Asset Tracking
- Freight Terminal Processes
- Drayage Operations
- Freight-Highway Connector System
- International Border Crossing Process

Figure 2.13.1
Taxonomy for Intermodal Freight

TABLE 2.13.1
BENEFITS AND COSTS OF ITS APPLICATIONS FOR INTERMODAL FREIGHT

Freight Tracking

Benefits

Goal Area	# of Studies	Impact	Example
Customer Satisfaction	1	?	During the Electronic Intermodal Supply Chain Manifest field operational test in Chicago, Illinois, and New York, New York, participants felt access to real-time cargo shipment information over the Internet was beneficial. Manufacturers, carriers, and airports that used the system felt it was easy to use, and were very satisfied with the system's capability of duplicating necessary business functions. The system was expected to improve operational efficiency if more fully deployed.[30]

Costs

Unit Costs Database	No data to report.
System Cost	No data to report.

Asset Tracking

Benefits

No data to report.

Costs

Unit Costs Database	Commercial Vehicle On-Board subsystem Fleet Management Center subsystem	See Appendix A
System Cost	A tracking device installed on fleet trailers can integrate GPS technology with the Internet to provide a secure cost-effective method for remote and accurate management of trailers. The self-powered unit has a rechargeable battery pack, a roof-mounted combination GPS and wireless antenna, and a roof- mounted solar panel.[31]	Cost: beginning at **$800** per trailer (2000) Monthly service cost: **$19** per subscriber with a 3-year contract (2000)

Impact Legend
- ++ substantial positive impacts
- + positive impacts
- o negligible impact
- +/– mixed results
- ? not enough data
- – negative impacts

Freight Terminal Processes

Benefits

Goal Area	# of Studies	Impact	Example
Productivity	1	?	An electronic supply chain manifest system implemented biometric and smart-card devices to automate manual paper-based cargo data transfers between manufacturers, carriers, and airports in Chicago, Illinois, and New York, New York. Although participation was limited, the system was expected to improve efficiency. The time required for truckers to accept cargo from manufacturers decreased by about four minutes per shipment, and the time required for airports to accept the deliveries decreased by about three minutes per shipment.[30]

Costs

Unit Costs Database	No data to report.
System Cost	No data to report.

International Border Crossing Process

Benefits

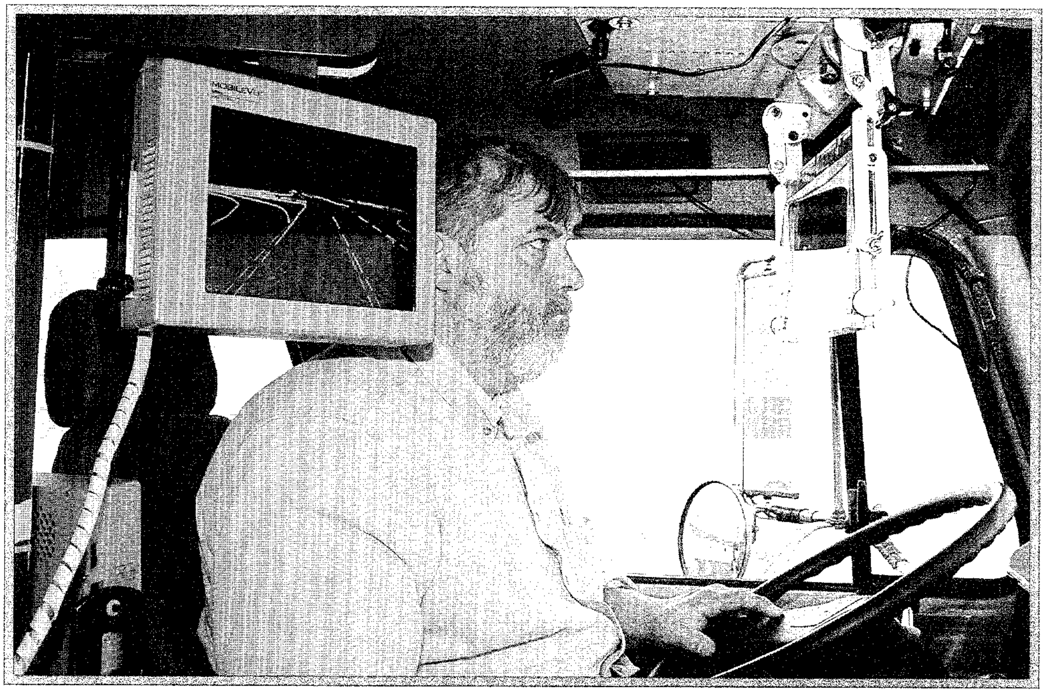
No data to report.

Costs

Unit Costs Database	Commercial Vehicle On-Board subsystem	See Appendix A
System Cost	No data to report.	

Impact Legend
- ++ substantial positive impacts
- \+ positive impacts
- o negligible impact
- +/– mixed results
- ? not enough data
- – negative impacts

3.0 Benefits and Costs of Intelligent Vehicles



INTELLIGENT VEHICLES

PROGRAM AREAS

- Collision Warning Systems
- Driver Assistance Systems
- Collision Notification Systems

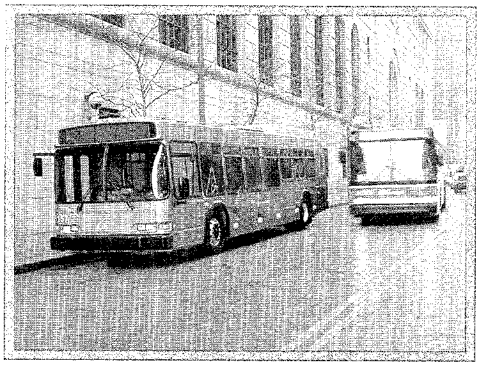
Figure 3.0.1
Taxonomy for Intelligent Vehicles

Intelligent vehicle applications of ITS use vehicle-mounted sensors and communications devices to assist with the safe operation of vehicles and mitigate the consequences of crashes that do occur. The many intelligent vehicle applications under various levels of development, testing, and deployment fall into three program areas as depicted in **Figure 3.0.1**. Collision warning systems monitor a vehicle's surroundings and provide warnings to the driver regarding dangerous conditions that may lead to a collision. Driver assistance systems provide information and in some cases assume partial control of the vehicle to assist with the safe operation of the vehicle. With the aim of speeding aid to victims after a crash occurs, collision notification systems alert responders when an accident occurs, with more advanced systems providing additional information on crash characteristics that can aid medical personnel.

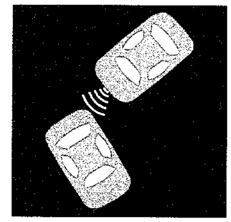
Sections 3.1 through 3.3 discuss each of these intelligent vehicle application areas in greater detail.

3.1 Collision Warning Systems

To improve the ability of drivers to avoid accidents, collision warning systems continue to be tested and deployed. Intersection collision warning systems are designed to detect and warn drivers of approaching traffic at high-speed intersections. Obstacle detection systems use vehicle-mounted sensors to detect obstructions, such as other vehicles, road debris, or animals, in a vehicle's path and alert the driver. Lane-change warning systems have been deployed to alert bus and truck drivers of vehicles, or other obstructions, in adjacent lanes when the driver prepares to change lanes. Road departure warning systems have been tested using machine vision and other in-vehicle systems to detect and alert drivers of potentially unsafe lane-keeping practices and to keep drowsy drivers from running off the road. In the application area of forward-collision warning systems, microwave radar and machine vision technology help detect and avert vehicle collisions. These systems typically use in-vehicle displays or audible alerts to warn drivers of unsafe following distances. If a driver does not properly apply brakes in a critical situation, some systems automatically assume control and apply the brakes in an attempt to avoid a collision. Rear-impact warning systems also use radar detection to prevent accidents; in this case, a warning sign is activated on the rear of the vehicle to warn tailgating drivers of impending danger. **Figure 3.1.1** summarizes the classification of benefits and costs under collision warning systems.



Intelligent Vehicles



Collision Warning Systems

- Intersection Collision Warning
- Obstacle Detection
- Lane Change
- Road Departure Warning
- Forward Collision Warning
- Rear Impact Warning

Figure 3.1.1
Taxonomy for Collision Warning Systems

While most collision warning systems (CWS) are still in the research, prototype, and testing phases, some (e.g., forward-collision warning and lane control) have begun to emerge in mainstream markets. Cost data are not readily available for collision warning systems in the early development stages or even for those systems in the commercial market. Much of the collision warning system cost data in reports and studies is based on estimates and/or market analysis of the public's willingness to pay for a specific in-vehicle feature. Hence, this section contains few examples of system cost data.

Table 3.1.1 provides information on the benefits and costs of collision warning systems. Information provided on the impacts of these systems is indicated using the symbols in the Impact Legend at the bottom corner of the following pages.

Table 3.1.1
Benefits and Costs of Collision Warning Systems

Intersection Collision Warning		
Benefits		
No data to report.		
Costs		
Unit Costs Database	Commercial Vehicle On-Board subsystem Vehicle On-Board subsystem	See Appendix A
System Cost	No data to report.	

Obstacle Detection				
Benefits				
Goal Area	**# of Studies**	**Impact**	**Example**	
Safety	1	?	A transport company in St. Nicholas, Quebec, Canada, was able to reduce at-fault accidents by 33.8% in the first year after the installation of a radar-based collision warning system. The system included a forward-looking sensor and a side sensor to warn drivers of obstacles in blind spots.[132]	
Costs				
Unit Costs Database	Commercial Vehicle On-Board subsystem Vehicle On-Board subsystem			See Appendix A
System Cost	The Pittsburgh Port Authority, in Pennsylvania, and Carnegie Mellon University's Robotics Institute have tested a collision avoidance system on 100 buses to warn bus drivers of obstacles in blind spots. The system consists of 12 ultrasonic sensors mounted on the side of the buses and an on-board computer.[133]			Cost: **$2,600** (approx.) per vehicle (2001)

Impact Legend
- ++ substantial positive impacts
- + positive impacts
- o negligible impact
- +/– mixed results
- ? not enough data
- – negative impacts

Lane Change

Benefits

Goal Area	# of Studies	Impact	Example
Safety	2	?	A study conducted by NHTSA indicated a lane change/merge crash avoidance system would be effective in 37% of crashes.[32]

Costs

Unit Costs Database	Commercial Vehicle On-Board subsystem Vehicle On-Board subsystem	See Appendix A
System Cost	A collision warning system (CWS) which uses radar technology can reduce sideswipes during lane changes and right turns.[33]	Average cost for CWS with forward-looking and side sensor: **$2,500**

Road Departure Warning

Benefits

Goal Area	# of Studies	Impact	Example
Safety	2	?	A study conducted by NHTSA indicated a road-departure countermeasure system would be effective in 24% of crashes.[32]

Costs

Unit Costs Database	Commercial Vehicle On-Board subsystem Vehicle On-Board subsystem	See Appendix A
System Cost	No data to report.	

Impact Legend
- ++ substantial positive impacts
- \+ positive impacts
- o negligible impact
- +/– mixed results
- ? not enough data
- – negative impacts

3.1 Collision Warning System

Forward Collision Warning			
Benefits			
Goal Area	**# of Studies**	**Impact**	**Example**
Safety	3	?	A NHTSA modeling study indicated collision warning systems would be effective in 42% of rear-end crash situations where the lead vehicle was decelerating, and effective in 75% of rear-end crashes where the lead vehicle was not moving. Overall, collision warning systems would be 51% effective.[32]

Costs		
Unit Costs Database	Commercial Vehicle On-Board subsystem Vehicle On-Board subsystem	See Appendix A
System Cost	A Florida-based trucking company has installed a collision warning system (CWS) to reduce the number of rear-end incidents. Adaptive cruise control can be added to further reduce rear-end collisions.[33,34]	Average cost for CWS with forward-looking and side sensor: **$2,500** Adaptive cruise control: **$350-$400** (extra)

Rear Impact Warning		
Benefits		
No data to report.		
Costs		
Unit Costs Database	Commercial Vehicle On-Board subsystem Vehicle On-Board subsystem	See Appendix A
System Cost	No data to report.	

Impact Legend
- ++ substantial positive impacts
- \+ positive impacts
- o negligible impact
- +/– mixed results
- ? not enough data
- – negative impacts

3.2 Driver Assistance Systems

Intelligent Transportation Systems that assist driving tasks continue to gain interest in the marketplace. In-vehicle navigation systems with GPS technology may reduce driver error, increase safety, and save time by improving driver decisions in unfamiliar areas. Integrated communication systems that enable drivers and dispatchers to coordinate re-routing decisions on-the-fly can also save time, money, and improve productivity. In-vehicle vision enhancement improves visibility for driving conditions involving reduced sight distance due to night driving, inadequate lighting, fog, drifting snow, or other inclement weather conditions. Intelligent cruise control, speed control, guidance/steering assistance, and coupling/decoupling systems which help transit operators link multiple buses or train cars into trains each assist drivers with routine tasks that weigh on driver workload. Recently, real-time on-board monitoring applications have been developed to track and report cargo condition, driver condition, safety and security, and the mechanical condition of vehicles equipped with in-vehicle diagnostics. In the event of an incident, in-vehicle safety event recorders can act like a "black box" and record vehicle performance data and other input from video cameras or radar sensors to improve the post-processing of accident data.

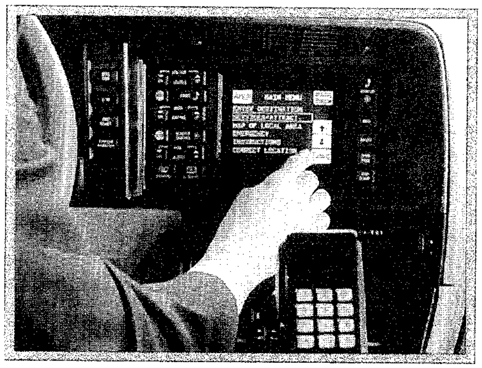
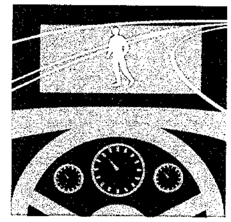


Figure 3.2.1 summarizes the classification of benefits and costs data for driver assistance systems.

While some driver assistance systems (e.g., vision enhancement, safety event recorders) are still in the research, prototype, and testing phases, others (e.g., navigation systems, on-board monitoring) have begun to emerge in mainstream markets. Cost data are not readily available for systems in the early development stages or even for those systems in the commercial market. Furthermore, many reports and studies on driver assistance systems contain little or no cost data, or are based on estimates and/or market analysis of the public's willingness to pay for a specific in-vehicle feature. Hence, this section contains few examples of system cost data.

Table 3.2.1 provides information on the benefits and costs of driver assistance systems. Information provided on the impacts of these systems is indicated using the symbols in the Impact Legend at the bottom corner of each page.

INTELLIGENT VEHICLES



DRIVER ASSISTANCE SYSTEMS

- **Navigation**
- **Driver Communication**
  - With Other Drivers
  - With Carrier/Dispatch
- **Vision Enhancement**
- **Intelligent Cruise Control**
- **Speed Control**
- **Guidance/Steering Assistance**
  - Electronic Towbar
- **Precision Docking**
- **Coupling/Decoupling**
- **On-Board Monitoring**
  - Cargo Condition
  - Safety & Security
  - Driver Condition
  - Vehicle Diagnostics
- **Safety Event Recorders**

Figure 3.2.1
Taxonomy for Driver Assistance Systems

TABLE 3.2.1
BENEFITS AND COSTS OF DRIVER ASSISTANCE SYSTEMS

Electronic Screening: Safety Screening

Benefits

Goal Area	# of Studies	Impact	Example
Safety	2	?	Safety impacts of in-vehicle navigation systems were estimated using simulation models and field data collected from the TravTek project. Results indicated users could decrease their crash risk by up to 4%.[134]
Mobility	4	+	The City Laboratories Enabling Organization of Particularly Advanced Telematics Research and Assessments (CLEOPATRA) project in Turin, Italy, demonstrated a time savings of more than 10% for cars equipped with in-vehicle navigation devices.[51]
Capacity/ Throughput	2	?	Capacity improvements from in-vehicle navigation systems were estimated using simulation models and field data from the TravTek project. Using a market penetration rate of 30%, and overall average trip duration as a surrogate for a given level of service, dynamic route guidance enabled the system to handle a 10% increase in demand.[134]
Customer Satisfaction	3	+	In-vehicle navigation units were distributed to public agencies in the San Antonio, Texas, area as part of the San Antonio MMDI. Focus groups composed of drivers of vehicles equipped with the units indicated that the drivers most satisfied with the system were those who frequently drove different routes each day, particularly paratransit drivers and police investigators.[19]

Costs

Unit Costs Database	Vehicle On-Board subsystem	See Appendix A
System Cost	In-vehicle navigation units were distributed to public agencies in the San Antonio, Texas, area as part of the San Antonio MMDI. The units provided route guidance and real-time traffic conditions. The cost of the units (590 at approximately $2,800 each) was the most significant cost driver for the project. Most of the O&M cost is attributed to database updates.[19]	Capital cost for project: **$2,388,691** (1998) Annual O&M cost: **$102,330** (1998)

Impact Legend
- ++ substantial positive impacts
- \+ positive impacts
- o negligible impact
- +/– mixed results
- ? not enough data
- – negative impacts

Driver Communication with Other Drivers

Benefits		
No data to report.		
Costs		
Unit Costs Database	Vehicle On-Board subsystem	See Appendix A
System Cost	No data to report.	

Driver Communication with Carrier/Dispatch

Benefits

Goal Area	# of Studies	Impact	Example
Productivity	2	+	An advanced routing and decision-making software communications program helped dispatchers organize and route time-sensitive delivery orders. The system increased the number of deliveries per driver-hour by 24%.[135]

Costs

Unit Costs Database	Transit Vehicle On-Board subsystem Commercial Vehicle On-Board subsystem Vehicle On-Board subsystem	See Appendix A
System Cost	The AVL system installed by the Regional Transit District (RTD) in Denver, Colorado, included the capability for voice and data communication between fleet vehicles and the dispatch center. The GPS/In-Vehicle Logic Unit/In-Vehicle Data Unit was approximately $3,517 per bus.[12]	System cost: **$10.4** million

Vision Enhancement

Benefits		
No data to report.		
Costs		
Unit Costs Database	Vehicle On-Board subsystem	See Appendix A
System Cost	No data to report.	

Impact Legend
- ++ substantial positive impacts
- \+ positive impacts
- ○ negligible impact
- +/– mixed results
- ? not enough data
- – negative impacts

Intelligent Cruise Control

Benefits

Goal Area	# of Studies	Impact	Example
Safety	1	+/–	Ten Intelligent Cruise Control (ICC) vehicles were equipped with automatic throttle modulation and down shifting (but not braking) to maintain preset headways during a NHTSA field test. The performance of the ICC was compared to conventional cruise control and manually operated vehicles. Results indicated that ICC vehicles made the fewest number of risky lane changes in response to slower traffic. Manually operated vehicles, however, had the quickest average response time to lead vehicle brake lights.[136]
Capacity/ Throughput	3	+	In the Netherlands, a simulation model investigated the impact of an automated braking system capable of automatically resetting itself after activation in the operational speed range of 30 to 150 km/hr. With a market penetration of 20%, and a headway setting of 0.8 seconds, the system increased capacity by 3.2%. However, if ICC headway was set at 1.2 seconds, capacity increased by only 1.0%.[137]
Customer Satisfaction	2	+	The ICC system deployed in the NHTSA field test generally had a very high level of acceptance by the participants. Participants overwhelmingly ranked ICC over the manual and conventional cruise control-equipped vehicles for convenience, comfort, and enjoyment. Participants indicated they would most likely use ICC on freeways.[136]
Energy/ Environment	3	+	Driver response and vehicle dynamics were recorded for one ICC vehicle and two manually operated vehicles in a single lane of freeway traffic. The ICC vehicle attempted to smooth traffic flow by minimizing the variance between acceleration and deceleration extremes. Simulation models based on collected field data estimated a fuel savings of 3.6% during scenarios with frequent acceleration and deceleration.[138]

Costs

Unit Costs Database	Vehicle On-Board subsystem	See Appendix A
System Cost	No data to report.	

Impact Legend
- ++ substantial positive impacts
- + positive impacts
- o negligible impact
- +/– mixed results
- ? not enough data
- – negative impacts

Speed Control

Benefits

Goal Area	# of Studies	Impact	Example
Customer Satisfaction	1	?	In the southern Swedish town of Eslov, 25 personal vehicles were equipped with governors activated by wireless beacons at city points-of-entry to limit inner city vehicle speeds to 50 km/hr. The vast majority of participants preferred this adaptive speed control over other physical countermeasures such as speed humps, chicanes, or mini-roundabouts.[139]

Costs

Unit Costs Database	Vehicle On-Board subsystem	See Appendix A
System Cost	No data to report.	

Guidance/Steering Assistance

Benefits

Goal Area	# of Studies	Impact	Example
Energy/ Environment	1	?	An electronic towbar system coupled two heavy-duty trucks without the aid of a mechanical towbar. The system enabled a trailing truck to autonomously follow a lead truck by a distance of approximately 10 meters. Track testing showed the lead truck and the trailing truck reduced fuel consumption by about 7% and 5 - 21%, respectively, when traveling at 80 km/hr.[140]

Costs

Unit Costs Database	Vehicle On-Board subsystem	See Appendix A
System Cost	No data to report.	

Impact Legend
- ++ substantial positive impacts
- + positive impacts
- o negligible impact
- +/– mixed results
- ? not enough data
- – negative impacts

3.2 Driver Assistance Systems

On-Board Monitoring: Cargo Condition		
Benefits		
No data to report.		
Costs		
Unit Costs Database	Commercial Vehicle On-Board subsystem	See Appendix A
System Cost	No data to report.	

On-Board Monitoring: Safety & Security		
Benefits		
No data to report.		
Costs		
Unit Costs Database	Transit Vehicle On-Board subsystem	See Appendix A
System Cost	No data to report.	

On-Board Monitoring: Driver Condition		
Benefits		
No data to report.		
Costs		
Unit Costs Database	Commercial Vehicle On-Board subsystem Vehicle On-Board subsystem	See Appendix A
System Cost	No data to report.	

Impact Legend
- ++ substantial positive impacts
- \+ positive impacts
- o negligible impact
- +/– mixed results
- ? not enough data
- – negative impacts

On-Board Monitoring: Vehicle Diagnostics

Benefits		
No data to report.		
Costs		
Unit Costs Database	Commercial Vehicle On-Board subsystem Vehicle On-Board subsystem	See Appendix A
System Cost	No data to report.	

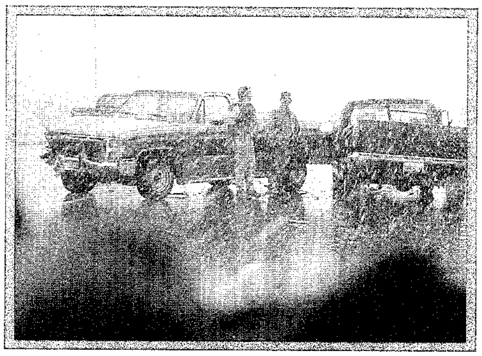
Safety Event Recorders

Benefits		
No data to report.		
Costs		
Unit Costs Database	Vehicle On-Board subsystem	See Appendix A
System Cost	No data to report.	

Impact Legend
++ substantial positive impacts
+ positive impacts
○ negligible impact
+/− mixed results
? not enough data
− negative impacts

3.3 Collision Notification Systems

In an effort to improve response times and save lives, collision notification systems have been designed to detect and report the location and severity of incidents to agencies and services responsible for coordinating appropriate emergency response actions. These systems can be activated manually (Mayday), or automatically (automatic collision notification). More advanced collision notification (ACN) systems use in-vehicle crash sensors, GPS technology, and wireless communications systems to supply public/private call centers with crash location information, and in some cases, the number of injured passengers and the nature of their injuries.



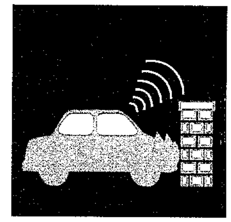
Advanced ACN data can assist responders in determining the type of equipment needed in an emergency (basic or advanced life support EMS units), mode of transport (air or ground), and the location of the nearest trauma center.

Over a dozen commercial Mayday/ACN products are available. Many of these products are available as factory-installed options on high-end luxury cars; others are installed as after-market products. The typical Mayday/ACN product utilizes location technology, wireless communication, and a third-party response center to notify the closest Public Safety Answering Point (PSAP) for emergency response. Cost data are available for many of the Mayday/ACN products, but are likely to change given future technology advancements and market trends. No cost data are available for advanced ACN technology.

Figure 3.3.1 summarizes the classification of benefits and costs data under collision notification.

Table 3.3.1 provides information on the benefits and costs of collision notification systems. Information provided on the impacts of these systems is indicated using the symbols in the Impact Legend at the bottom corner of each page.

Intelligent Vehicles



Collision Notification Systems

- Mayday/ACN
- Advanced ACN

Figure 3.3.1
Taxonomy for Collision Notification Systems

TABLE 3.3.1
BENEFITS AND COSTS OF COLLISION NOTIFICATION SYSTEMS

Mayday/ACN

Goal Area	# of Studies	Impact	Example
Benefits			
Customer Satisfaction	1	?	The Puget Sound Help Me (PuSHMe) Mayday System allowed a driver to immediately contact a response center, transmit GPS coordinates, and request assistance. Survey responses were collected from 23 participants equipped with Mayday voice communication systems, and 54 participants equipped with Mayday text messaging. The surveys indicated 95% of drivers felt more secure if equipped with Mayday voice communications, and 70% of drivers felt more secure if equipped with Mayday text messaging.[141]

Costs		
Unit Costs Database	Vehicle On-Board subsystem	See Appendix A
System Cost	Numerous commercial Mayday/ACN products are available as factory-installed and after-market devices. Cost data are more prevalent for after-market devices than for factory-installed systems. Installation costs were not readily available. Annual service fees vary depending on the level of services offered.[36]	After market device cost range: **$400-$1,895** Monthly service fee: **$10-$27**

Advanced ACN

Goal Area	# of Studies	Impact	Example
Benefits			
Safety	1	?	Between July 1997 and August 2000, the impacts of advanced ACN on incident notification were tracked for vehicles with and without ACN systems in urban and suburban areas of Erie County, New York. Based on a limited number of crash events, the average notification time for vehicles equipped with ACN was less than one minute with some notification times as long as two minutes, and the average notification time for vehicles without ACN was about three minutes with some notification times as long as 9, 12, 30, and 46 minutes.[35]

Costs		
Unit Costs Database	Vehicle On-Board subsystem	See Appendix A
System Cost	No data to report.	

Impact Legend
- ++ substantial positive impacts
- \+ positive impacts
- ○ negligible impact
- +/– mixed results
- ? not enough data
- – negative impacts

4.0 Summary and Conclusions

This report has presented many of the findings on the benefits and costs of ITS accumulated in the ITS Benefits and Unit Costs Database. New in this 2003 report is the inclusion of cost information for representative ITS deployments, as well as relevant unit cost data for components of the various applications. Significant amounts of information are available for many ITS services, but many gaps in knowledge also exist. In general, ITS services have shown some positive benefit, but the authors have identified a number of areas with mixed results, not enough information, or negligible impacts. While reported negative impacts are usually outweighed by other positive impacts, a few evaluations have identified opportunities for improvement in future deployments. The reader should note that reported results are highly sensitive to the deployment environment.

Table 4.0.1 contains the number of source documents within the ITS Benefits Database covering each goal area within the major program areas identified in the taxonomy. This illustration demonstrates that a significant number of studies are accumulating in a number of areas, especially arterial and freeway management systems. However, there is much to be learned in many areas of ITS implementation. **Table 4.0.1** demonstrates the clear need for continuing evaluation of ITS implementations in the areas of information management, roadway operations and maintenance, intermodal freight, collision warning, and collision notification.

Number of References

○ – 0
◔ – 1 to 3
◑ – 4 to 6
◕ – 7 to 10
● – >10

TABLE 4.0.1. DOCUMENTS AVAILABLE IN THE ITS BENEFITS DATABASE

(as of 31 January 2003)

Taxonomy Program Areas	Safety	Mobility	Capacity/ Throughput	Productivity	Customer Satisfaction	Energy & Environment
Arterial Management Systems	●	●	◑	◕	◕	●
Freeway Management Systems	●	●	◕	◔	◕	◑
Transit Management Systems	◑	◕	◔	◕	◕	◔
Incident Management Systems	◕	●	○	◕	◑	◑
Emergency Management Systems	◔	◔	○	◔	◔	○
Electronic Payment Systems	◔	◑	◔	◑	◑	◑
Traveler Information	◔	●	◔	○	●	◔
Information Management	○	○	○	○	○	○
Crash Prevention & Safety	●	◑	○	○	◔	◔
Roadway Operations & Maintenance	◔	◔	○	○	◔	○
Road Weather Management	●	◔	◔	◕	◔	◔
Commercial Vehicle Operations	◑	◕	○	●	◑	◔
Intermodal Freight	○	○	○	◔	◔	○
Collision Warning Systems	◑	○	○	◔	◔	◔
Driver Assistance Systems	◑	●	◑	◑	◕	◑
Collision Notification Systems	◔	○	○	○	◔	○

Table 4.0.2 presents the number of benefits sources/references currently in the ITS Benefits Database and an indication of system cost examples in this report for each of the taxonomy program and application areas. While the previous table demonstrated that a significant amount of evaluation has occurred in several of the broad program areas, there is still a need for further research into the effects of many of the various types of applications within these categories. For example, **Table 4.0.2** demonstrates that, while there are numerous evaluation reports in the database covering arterial management systems, parking management is one application area that would benefit from further study. Totals by category presented in this table do not always equal the sum of those reported in the body of this report. A number of reports in the database discuss evaluations of larger systems which include several ITS applications, appearing several times in the totals in **Table 4.0.2**; however, the evaluation findings appear in the body of the report within the application area most directly responsible for the impact cited. For example, an evaluation of an arterial management system providing data to a traveler information system would appear in both categories below, but only within the traveler information section in the body of the report.

As indicated in Table **4.0.2**, examples of system cost data are available for the majority of the Intelligent Infrastructure application areas with the exception of Intermodal Freight. However, system cost data are still needed for a few of the newer ITS application areas such as variable speed limits on arterials, lane management strategies, and transit security. Examples of system cost data are not prevalent in the Intelligent Vehicle application areas. This lack of cost data can be attributed to the fact that many Intelligent Vehicle applications are still in the research and prototype phases. Cost data in many cases, if available, are based on estimates and/or market analysis of the public's willingness to pay for a specific feature.

Table 4.0.2
Summary of Benefits Sources/References and System Cost Data

(as of 31 January 2003)

Taxonomy Program and Application Areas	Benefits Sources/References	System Costs Data
Intelligent Infrastructure		
Arterial Management Systems		
Traffic Surveillance	3	✓
Traffic Control: Transit Signal Priority	14	✓
Traffic Control: Emergency Vehicle Preemption	4	✓
Traffic Control: Adaptive Signal Control	18	✓
Traffic Control: Advanced Signal Systems	15	✓
Traffic Control: Variable Speed Limits	0	
Traffic Control: Bicycle & Pedestrian	1	✓
Traffic Control: Special Events	1	
Lane Management	0	
Parking Management	1	✓
Information Dissemination	5	
Enforcement: Speed Enforcement	4	✓
Enforcement: Stop/Yield Enforcement	14	✓
Freeway Management Systems		
Traffic Surveillance	7	✓
Ramp Control: Ramp Metering	15	✓
Ramp Control: Ramp Closure	0	
Ramp Control: Priority Access	0	
Lane Management: HOV Facilities	1	
Lane Management: Reversible Flow Lanes	0	
Lane Management: Pricing	0	
Lane Management: Variable Speed Limits	1	✓
Lane Management: Emergency Evacuation	0	
Special Event Transportation Management	0	
Information Dissemination	14	✓
Enforcement	9	✓
Transit Management Systems		
Safety & Security: On-Vehicle Surveillance	1	✓
Safety & Security: Facility Surveillance	1	
Safety & Security: Employee Credentialing	0	
Safety & Security: Remote Disabling Systems	0	

Taxonomy Program and Application Areas	Benefits Sources/References	System Costs Data
Intelligent Infrastructure		
Transit Management Systems ***continued***		
Transit Demand Management: Ride Sharing/Matching	0	
Transit Demand Management: Dynamic Routing/Scheduling	4	✓
Transit Demand Management: Service Coordination	1	
Fleet Management: AVL/CAD	12	✓
Fleet Management: Maintenance	1	
Fleet Management: Planning	0	
Information Dissemination: In-Vehicle Systems	0	✓
Information Dissemination: In-Terminal/Wayside	1	✓
Information Dissemination: Internet/Wireless/Phone	2	✓
Incident Management Systems		
Surveillance & Detection	18	✓
Mobilization & Response	16	✓
Information Dissemination	6	✓
Clearance & Recovery: Investigation	1	✓
Clearance & Recovery: Video	0	
Clearance & Recovery: Temporary Traffic Control	0	
Emergency Management Systems		
Hazardous Materials Management	1	
Emergency Medical Services: Advanced ACN	1	
Emergency Medical Services: Telemedicine	1	✓
Response & Recovery: Evacuation Operations	0	
Response & Recovery: Response Management	1	✓
Electronic Payment Systems		
Toll Collection	10	✓
Transit Fare Payment	6	✓
Multi-use Payment	1	
Traveler Information		
Pre-trip Information	29	✓
En Route Information	27	✓
Tourism & Events	1	✓
Information Management		
Data Archiving	0	✓

Taxonomy Program and Application Areas	Benefits Sources/References	System Costs Data
Intelligent Infrastructure		
Crash Prevention & Safety		
Road Geometry Warning Systems: Ramp Rollover	3	✓
Road Geometry Warning Systems: Curve Speed Warning	1	
Road Geometry Warning Systems: Downhill Speed Warning	3	✓
Road Geometry Warning Systems: Overheight/Overwidth Warning	0	
Highway-Rail Crossing Systems	5	✓
Intersection Collision Warning	1	
Pedestrian Safety	0	✓
Bicycle Warning Systems	0	✓
Animal Warning Systems	0	✓
Roadway Operations & Maintenance		
Information Dissemination	1	✓
Asset Management: Fleet Management	0	✓
Asset Management: Infrastructure Management	0	
Work Zone Management	3	✓
Road Weather Management		
Surveillance, Monitoring, & Prediction	7	✓
Information Dissemination	6	✓
Traffic Control	6	✓
Response & Treatment	7	✓
Commercial Vehicle Operations		
Credentials Administration: Electronic Funds	2	
Credentials Administration: Electronic Registration/Permitting	8	✓
Safety Assurance: Safety Information Exchange	5	✓
Safety Assurance: Automated Inspection	2	
Electronic Screening: Safety Screening	4	
Electronic Screening: Border Clearance	4	
Electronic Screening: Weight Screening	6	
Electronic Screening: Credential Checking	4	✓
Carrier Operations & Fleet Management: AVL/CAD	4	✓
Carrier Operations & Fleet Management: On-Board Monitoring	3	
Carrier Operations & Fleet Management: Traveler Information	1	
Security Operations	0	

Taxonomy Program and Application Areas	Benefits Sources/References	System Costs Data
Intelligent Infrastructure		
Intermodal Freight		
Freight Tracking	1	
Asset Tracking	0	✓
Freight Terminal Processes	1	
Drayage Operations	0	
Freight-Highway Connector System	0	
International Border Crossing Process	0	
Intelligent Vehicles		
Collision Warning Systems		
Intersection Collision Warning	0	
Obstacle Detection	1	✓
Lane Change	2	✓
Road Departure Warning	2	
Forward Collision Warning	3	✓
Rear Impact Warning	0	
Driver Assistance Systems		
Navigation	8	✓
Driver Communication: With Other Drivers	0	
Driver Communication: With Carrier/Dispatch	2	✓
Vision Enhancement	0	
Intelligent Cruise Control	5	
Speed Control	2	
Guidance/Steering Assistance	3	
Precision Docking	0	
Coupling/Decoupling	0	
On-Board Monitoring	2	
Safety Event Recorders	0	
Collision Notification Systems		
Mayday/ACN	1	✓
Advanced ACN	1	

Interested readers are encouraged to submit additional evaluation reports, covering any area of ITS, via the online database. Cost data for implemented ITS applications are also welcome, and will help keep the estimates provided in the online Unit Costs Database up-to-date. The reader is reminded to check online for the most current information on benefits and costs at **www.benefitcost.its.dot.gov**.

4.0 Summary and Conclusions

The level of ITS deployment in the U.S. and worldwide continues to increase (see **www.itsdeployment.its.dot.gov**). As experience with additional applications increases, additional impacts will become apparent, and further information on the costs of ITS implementation will become available. Implementing agencies will also learn valuable lessons regarding appropriate implementation and operational strategies. The ITS Joint Program Office will continue to make this information available via the JPO website at **www.its.dot.gov**, the ITS Benefits and Unit Costs Database at **www.benefitcost.its.dot.gov**, the Electronic Document Library at **www.its.dot.gov/itsweb/welcome.htm**, and other publications.

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APPENDIX A: ITS UNIT COSTS DATABASE

(as of September 30, 2002)

Subsystem/Unit Cost Element	IDAS No.^	Lifetime* (years)	Capital Cost ($K)		O&M Cost ($K/year)		Notes
			Low	High	Low	High	
Roadside Telecommunications (RS-TC)							
DS0 Communication Line	TC001	20	0.5	1	0.6	1.2	56 Kbps capacity. Leased with typical distance from terminus to terminus is 8 - 15 miles, but most of the cost is not distance-sensitive.
DS1 Communication Line	TC002	20	0.5	1	4.8	8.4	1.544 Mbps capacity (T1 line). Leased with typical distance from terminus to terminus is 8 - 15 miles, but most of the cost is not distance-sensitive.
DS3 Communication Line	TC003	20	3	5	24	72	44.736 Mbps capacity (T3 line). Leased with typical distance from terminus to terminus is 8 - 15 miles, but most of the cost is not distance-sensitive.
ISP Service Fee	TC007				0.12	0.18	Monthly service fee ($10 to $15 per month).
Direct Bury Armor Encased Fiber Cable				60		0.02	Cost is per mile.
Conduit Design and Installation - Corridor		20		65		0.02	Cost is per mile.
Twisted Pair Installation		20		12		0.02	Cost is per mile.
Fiber Optic Cable Installation		20		20		0.02	Cost is per mile.
Telephone Drop			1	3	0.2	0.3	Cost is per drop.
Cellular Communication				0.5	0.3	0.4	Cost is for one unit.
900 MHz Spread Spectrum Radio		10		9	0.15	0.4	Cost is per link.
Microwave Communication		10		15	0.3	0.7	Cost is per link.
Wireless Communications, Low Usage	TC004				0.18	0.2	125 Kbytes/month available usage (non-continuous use).
Wireless Communications, Medium Usage	TC005				0.6	0.7	1,000 Kbytes/month available usage (non-continuous use).
Wireless Communications, High Usage	TC006	20	0.5	1	1.2	1.8	3,000 Kbytes/month available usage (non-continuous use).
Call Box		10		5.9		0.714	Capital cost includes call box and installation. O&M is cost per unit (per year) for service maintenance contract and annual cellular service fee.
Roadside Detection (RS-D)							
Inductive Loop Surveillance on Corridor		5	3	8	0.5	0.8	Double set (4 loops) with controller, power, etc.
Inductive Loop Surveillance at Intersection		5	9	16	1	1.6	Four legs, 2 lanes/approach.
Machine Vision Sensor on Corridor			21.7	29	0.2	0.4	One sensor both directions of travel.
Machine Vision Sensor at Intersection			20	25.7		0.2	Four-way intersection, one camera per approach.
Passive Acoustic Sensor on Corridor			3.7	8	0.2	0.4	Cost range is for a single sensor covering up to 5 lanes. Low cost is for basic sensor, which consists of the sensor, mounting kit, junction box, and cabinet termination card. High cost includes basic sensor with solar and wireless option. This option consists of an antenna, solar charger, battery, & panel, and wireless base station, which will handle up to 8 sensors. Capital costs do not include installation or mounting structure.

^ Applicable only to unit cost elements used in IDAS. * Not available for all unit cost elements.

Subsystem/Unit Cost Element	IDAS No.^	Lifetime* (years)	Capital Cost ($K)		O&M Cost ($K/year)		Notes
			Low	High	Low	High	
Roadside Detection (RS-D) *continued*							
Passive Acoustic Sensor at Intersection			5	15	0.2	0.4	Four sensors, 4-leg intersection.
Remote Traffic Microwave Sensor on Corridor		10		6		0.1	One sensor both directions of travel. Includes installation.
Remote Traffic Microwave Sensor at Intersection		10		18		0.1	Four sensors, 4-leg intersection. Includes installation.
CCTV Video Camera	RS007	10	7.5	17	1.5	2.4	Cost includes color video camera with pan, tilt, and zoom (PTZ), and installation.
CCTV Video Camera Tower	RS008	20		12			Cost is for a 90-ft. aluminum pole; includes foundation, pole, conduit, and labor. Cost will be lower for a lower height pole.
Automated Flood Warning System				42			Includes sensors (rain, water level, weather, etc.) in the field which report via radio to a central receiver/decoder, which then sends data to a base station computer for storage and analysis.
Pedestrian Detection							
Microwave				0.6			Cost is per device. Typical deployment consists of 2 devices per crosswalk for detection of pedestrian in crosswalk. Can be used for detection of pedestrian at the curbside.
Infrared				0.3			Cost is per device. Typical deployment consists of 2 devices per crosswalk for detection of pedestrian at the sidewalk. Can be used for detection of pedestrian in the crosswalk.
Environmental Sensing Station (Weather Station)		25	10	50	1.9	4.1	Environmental Sensing Station (ESS), also known as a weather station, consists of pavement temperature sensor, subsurface temperature sensor, precipitation sensor (type & rate), wind sensor (speed & direction), air temperature and humidity sensors, visibility sensors, and remote processing unit (RPU). ESS provide condition data and are basic components of larger Road Weather Information Systems (see RWIS under TMC subsystem). RPU replaced every 5 years at $6.4K. O&M includes calibration, equipment repairs, and replacement of damaged equipment. O&M costs could be higher if state provided maintenance.
Traffic Camera for Red Light Running Enforcement			75	136	60		Low capital range is for a 35-mm wet film camera, which includes installation of the camera ($25K) and associated equipment (e.g., pole, loop detectors, cabinet foundation). High capital range is for digital camera, which includes a total of 2 cameras for a 3-lane approach. O&M cost is for one 35-mm wet film camera per year. Note, most jurisdictions contract with a vendor to install and maintain, and process the back office functions of the RLR system. The vendor receives compensation from fines charged to violators.
Lowering System		20	5	8			The lowering system includes the pole. Cost is for a typical 50-ft. steel pole and lowering system. The lowering system is available for use with all types of poles (e.g., steel, concrete, aluminum, fiberglass) and virtually any mounting height and with any ITS pole-mounted device (e.g., CCTV cameras, radar traffic detectors). Installation costs not included. The lowering system is mechanically operated; requires routine lubrication.

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Subsystem/Unit Cost Element	IDAS No.^	Lifetime* (years)	Capital Cost ($K)		O&M Cost ($K/year)		Notes
			Low	High	Low	High	
Roadside Detection (RS-D) ***continued***							
Portable Speed Monitoring System		15	9	15			Trailer-mounted two-digit dynamic message sign, radar gun, computer; powered by generator or operates off of solar power; requires minimal operations and maintenance work. The system determines a vehicle's speed with the radar gun and displays the current speed, in real time, and also stores the speeds in a computer for further analysis.
Roadside Control (RS-C)							
Linked Signal System LAN	RS002	20	40	70	0.4	0.8	Linked signal system LAN.
Signal Controller Upgrade for Signal Control	RS003	20	2.5	10	0.2	0.5	Per intersection.
Signal Controller			11	17.5	0.2	0.9	Includes installation of traffic signal controller per intersection.
Traffic Signal			95	115	2.4	3	Includes installation for one signal (four-leg intersection). Costs range from traffic signal with inductive loop detection to non-intrusive detection.
Signal Preemption Receiver	RS004	5	2	8	0.05	0.2	Two per intersection. Complement of IDAS elements RS005 and TV004.
Signal Controller Upgrade for Signal Preemption	RS005	10	2	5			Add-on to base capability (per intersection). Complement of IDAS elements RS004 and TV004.
Roadside Signal Preemption/ Priority			2.5	5.5			Includes infrared detector, detector cable, phase selector, and system software. Capital costs range is for 2-directions (low) and 4-directions (high). Does not include installation costs. Complement to transit (or emergency vehicle) on-board Signal Preemption/Priority Emitter.
Ramp Meter	RS006	5	30	50	1.5	3.5	Per location. Includes controller, power, etc.
Software for Lane Control	RS011	20	25	50	2.5	5	Software and hardware at site. Software is off-the-shelf technology and unit price does not reflect product development.
Lane Control Gates	RS012	20	100	150	2	3	Per location.
Fixed Lane Signal	RS009	20	6	8	0.6	0.8	Cost per signal.
Automatic Anti-icing System							
Short span		12	25		2		Typical automatic anti-icing system consists of a control system, chemical storage tank, distribution lines, pump, and nozzles. Pump and control hardware replaced every 5 years at cost of $3.5K. For a short-span system ranging from 120 to 180 feet. O&M includes system maintenance, utilities, materials, and labor.
Long Span		12	50	495	1.5	29.5	Typical automatic anti-icing system consists of a control system, chemical storage tank, distribution lines, pump, and nozzles. Pump and control hardware replaced every 5 years at cost of $3.5K. For a long-span system ranging from 320 feet to greater than 1/2 mile. O&M includes system maintenance, utilities, materials, and labor. The high O&M cost is for a much larger system; hence, the need for a greater amount of materials.

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Subsystem/Unit Cost Element	IDAS No.^	Lifetime* (years)	Capital Cost ($K)		O&M Cost ($K/year)		Notes
			Low	High	Low	High	
Roadside Information (RS-I)							
Roadside Message Sign	RS010	20	50	75	2.5	3.75	Fixed message board for HOV and HOT lanes.
Wireline to Roadside Message Sign	RS013	20	6	9			Wireline to VMS (0.5 mile upstation).
Variable Message Sign	RS015	20	48	120	2.4	6	Low capital cost is for smaller VMS installed along arterial. High capital cost is for full matrix, LED, 3-line, walk-in VMS installed on freeway.
Variable Message Sign Tower	RS016	20	25	125			Low capital cost is for a cantilever structure. High capital cost is for a truss structure that will span across 3-4 lanes. VMS tower structure requires minimal maintenance.
Variable Message Sign - Portable		14	21.5	25.5	1.2	2	Trailer-mounted VMS (3-line, 8-inch character display); includes trailer, solar or diesel powered.
Highway Advisory Radio	RS017	20	16	32	0.6	1	Capital cost is for a 10-watt HAR. Includes processor, antenna, transmitters, battery back-up, cabinet, rack mounting, lighting, mounts, connectors, cable, and license fee. Super HAR costs an additional $9 - 10K (larger antenna). Primary use of the super HAR is to gain a stronger signal.
Highway Advisory Radio Sign		10	5		0.25		Cost is for an HAR sign with flashing beacons and variable message capability. Includes cost of the controller.
Roadside Probe Beacon	RS020	5	5	8	0.5	0.8	Two-way device (per location).
LED Count-down Signal		10	0.325	0.45			Costs range from low (2 12x12-inch dual housing unit) to high (1 16x18-inch single housed unit). Signal indicates time remaining for pedestrian to cross, and a walk or don't walk icon. Count-down signals use low 8-watt LED bulbs, which require replacement approximately every 5 - 7 years.
Pedestrian Crossing Illumination System		5	27.5	42	2.75	4.2	The capital cost range includes cost of equipment and installation. Equipment includes fixtures - 4 lamps per lane - for a three-lane crosswalk, controller, pole, and push-button activator. Installation is estimated at 150 - 200% of total equipment cost. Capital cost would be greater if system included automated activation of in-pavement lighting system. O&M is approximately 10% of equipment cost.
Variable Speed Display Sign			3.7	5			Low range is for a variable speed-limit display system. High range includes static speed sign, speed detector (radar), and display system.
Roadside Rail Crossing (R-RC)							
Rail Crossing 4-Quad Gate, Signals	RS021	20	115	130	4.25	4.85	Gates and signals.
Rail Crossing Train Detector	RS022	20	16	21.5	0.77	1.03	Train detector circuitry and communication line from intelligent interface controller (IIC) to wayside interface equipment (WIE). Assume two-track crossing with two 0.5-mile communication lines.
Rail Crossing Controller	RS023	10	8	10	0.4	0.5	Intelligent interface controller (IIC).
Rail Crossing Pedestrian Warning Signal, Gates	RS024	20	10	15	0.2	0.3	Pedestrian warning signal and gates.
Rail Crossing Trapped Vehicle Detector	RS025	10	25	30	1.25	1.5	Entrapped vehicle detection camera, with poles and controller.

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Subsystem/Unit Cost Element	IDAS No.^	Lifetime* (years)	Capital Cost ($K)		O&M Cost ($K/year)		Notes
			Low	High	Low	High	
Parking Management (PM)							
Entrance/Exit Ramp Meters		10	2	5	0.2	0.5	Ramp meters are used to detect and count vehicles entering/existing the parking facility. O&M costs based on annual service contract.
Tag Readers		10	2	5	0.2	0.5	Readers support electronic payment scheme. O&M costs based on annual service contract.
Database and Software for Billing & Pricing		10	10	15	1	2	Database system contains parking pricing structure and availability. O&M costs based on annual service contract.
Parking Monitoring System		10	14	46			Includes installation, detectors, and controllers.
Hardware		5	2	11.5	0.2	1.15	Low end includes PC and printer. High range is the central computer system (PC, diagnostic PC, and software). O&M costs based on annual service contract.
Toll Plaza (TP)							
Electronic Toll Reader	TP001	10	2	5	0.2	0.5	Readers (per lane).
High-Speed Camera	TP002	10	5	10	0.5	1	Cost includes 1 camera/2 lanes.
Electronic Toll Collection Software	TP003	10	5	10			Includes COTS software and database.
Electronic Toll Collection Structure	TP004	20	10	15			Mainline structure.
Remote Location (RM)							
CCTV Camera	RM001	10	4	5	0.08	0.1	Interior fixed-mount camera for security.
Integration of Camera with Existing Systems	RM002	10	2	2.5			Per location.
Informational Kiosk	RM003	7	9.55	50	0.955	5	Includes hardware, enclosure, installation, modem server, and map software for indoor and outdoor.
Integration of Kiosk with Existing Systems	RM004	7	2.2	27.4			Software costs are for COTS (low) and developed/ outdoor (high).
Kiosk Upgrade for Interactive Usage	RM005	5	5	8	0.5	0.8	Interactive information display interface (upgrade from existing interface).
Kiosk Software Upgrade for Interactive Usage	RM006	5	10	12			Software is COTS.
Transit Status Information Sign		10		5.5			An LED display installed at transit terminal that provides status information on transit arrival.
Smart Card Vending Machine	RM007	5	37	40	1.85	2	Ticket vending machine for smart card.
Software, Integration for Smart Card Vending	RM008	20	3	5			Software is COTS.
Emergency Response Center (ER)							
Basic Facilities, Comm for Large Area	EM006		4000	4000	400	600	For population >750,000. Based on purchase of building rather than leasing space. Communications includes communications equipment internal to the facility such as equipment racks, multiplexers, modems, etc.
Basic Facilities, Comm for Medium Area	EM007		3200	3200	400	480	For population <750,000 and >250,000. Based on purchase of building rather than leasing space. Communications includes communications equipment internal to the facility such as equipment racks, multiplexers, modems, etc.

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Subsystem/Unit Cost Element	IDAS No.^	Lifetime* (years)	Capital Cost ($K)		O&M Cost ($K/year)		Notes
			Low	High	Low	High	
Emergency Response Center (ER) *continued*							
Basic Facilities, Comm for Small Area	EM008		2800	2800	400	420	For population <250,000. Based on purchase of building rather than leasing space. Communications includes communications equipment internal to the facility such as equipment racks, multiplexers, modems, etc.
Emergency Response Hardware	EM001	10	15	30	0.3	0.6	Includes 3 workstations.
Emergency Response Software	EM002	10	70	150	0.5	3.5	Includes emergency response plans database, vehicle tracking software, and real-time traffic coordination.
Emergency Response Labor	EM003				50	165	Two people. Salary costs are fully loaded including salary, overtime, overhead, benefits, etc.
Emergency Management Communications Software	EM004	20	5	10	2.5	5	Shared database between 4 sites. Cost is per site; software is COTS.
Hardware, Software Upgrade for E-911 and Mayday	EM005	10	105	180	1.7	2.5	Data communications translation software, E911 interface software, processor, and 3 workstations.
800 MHz. 2-way Radio		5	0.8	1.7	0.09	0.12	Cost is per radio.
Emergency Vehicle On-Board (EV)							
Communications Interface	EV001	10	0.3	2		0.02	Emergency vehicle communications. Cost is per vehicle.
Signal Preemption/Priority Emitter			0.5	2.1			Data-encoded emitter, manually initiated. Complement to Roadside Signal Preemption/ Priority (see Roadside Control subsystem).
Information Service Provider (ISP)							
Basic Facilities, Comm for Large Area	IS019		4000	4000	400	600	For population >750,000 (stand-alone). Based on purchase of building rather than leasing space. Communications includes communications equipment internal to the facility such as equipment racks, multiplexers, modems, etc.
Basic Facilities, Comm for Medium Area	IS020		3200	3200	400	480	For population <750,000 and >250,000 (stand-alone). Based on purchase of building rather than leasing space. Communications includes communications equipment internal to the facility such as equipment racks, multiplexers, modems, etc.
Basic Facilities, Comm for Small Area	IS021		2800	2800	400	420	For population <250,000 (stand-alone). Based on purchase of building rather than leasing space. Communications includes communications equipment internal to the facility such as equipment racks, multiplexers, modems, etc.
Information Service Provider Hardware	IS001	5	40.5	49.5	0.81	0.99	Includes 2 servers and 5 workstations.
Systems Integration	IS017	20	90	110			Integration with other systems.
Information Service Provider Software	IS002	20	275	550	13.75	27.5	Includes database software (COTS) and traffic analysis software.
Map Database Software	IS003	2	15	30			Software is COTS.
Information Service Provider Labor	IS004				175	250	2 Staff @ 50K to 75K and 1 staff @ 75K to 100K. Salary costs are fully loaded prices and include base salary, overtime, overhead, benefits, etc.
FM Subcarrier Lease	IS005				120	240	Cost is per year.

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Subsystem/Unit Cost Element	IDAS No.^	Lifetime* (years)	Capital Cost ($K)		O&M Cost ($K/year)		Notes
			Low	High	Low	High	
Information Service Provider (ISP) ***continued***							
Hardware Upgrade for Interactive Information	IS006	5	18.9	23.1	0.378	0.462	Includes 1 server and 2 workstations.
Software Upgrade for Interactive Information	IS007	20	250	500	12.5	25	Trip planning software (includes some development costs).
Added Labor for Interactive Information	IS008				100	150	1 Staff @ 50K to 75K for 2 shifts. Salary costs are fully loaded prices including base salary, overtime, overhead, benefits, etc.
Software Upgrade for Route Guidance	IS009	20	250	500	12.5	25	Route selection software. Software is COTS.
Map Database Upgrade for Route Guidance	IS010	2	100	200			Map database software upgrade.
Hardware Upgrade for Emergency Route Planning	IS011	5	13.5	16.5	0.27	0.33	Includes 1 server.
Software Upgrade for Emergency Route Planning	IS012	20	50	100	2.5	5	Route guidance software. Software is COTS.
Hardware Upgrade for Dynamic Ridesharing	IS013	5	5.4	6.6	0.108	0.132	Includes 2 workstations.
Software Upgrade for Dynamic Ridesharing	IS014	20	100	200	5	10	Software includes some development cost.
Added Labor for Dynamic Ridesharing	IS015				100	150	1 Staff @ 50K to 75K for 2 shifts. Salary costs are fully loaded prices including base salary, overtime, overhead, benefits, etc.
Liability Insurance for Dynamic Ridesharing	IS016				50	100	50K to 100K per year.
Software Upgrade for Probe Information Collection	IS018	20	250	500	12.5	25	Software includes COTS and some development cost.
Cable TV Traffic Channel Hardware		5		19			Includes hyperconverter, Pentium PC, TV, converter card, video mux, and demux.
Cable Channel Airtime						78	Cost is per year.
Transportation Management Center (TMC)							
Basic Facilities, Comm for Large Area	TM040		4000	4000	400	600	For population >750,000. Based on purchase of building rather than leasing space. Communications includes communications equipment internal to the facility such as equipment racks, multiplexers, modems, etc.
Basic Facilities, Comm for Medium Area	TM041		3200	3200	400	480	For population <750,000 and >250,000. Based on purchase of building rather than leasing space. Communications includes communications equipment internal to the facility such as equipment racks, multiplexers, modems, etc.
Basic Facilities, Comm for Small Area	TM042		2800	2800	400	420	For population <250,000. Based on purchase of building rather than leasing space. Communications includes communications equipment internal to the facility such as equipment racks, multiplexers, modems, etc.
Hardware for Signal Control	TM001	5	15	30			Includes 3 workstations.
Software, Integration for Signal Control	TM006	5	180	220			Software and integration, installation and 1 year maintenance. Software is COTS.

^ Applicable only to unit cost elements used in IDAS. * Not available for all unit cost elements.

Subsystem/Unit Cost Element	IDAS No.^	Lifetime* (years)	Capital Cost ($K)		O&M Cost ($K/year)		Notes
			Low	High	Low	High	
Transportation Management Center (TMC) ***continued***							
Labor for Signal Control	TM002				486	594	Costs include labor for operations (2 @ 50% of the time, at 100K), transportation engineer (1 at 50% of the time, at 100K), update timing plans (2K per system per month for every 10 systems), and signal maintenance technician (2 @ 75K). Salary cost are fully loaded prices including base salary, overtime, overhead, benefits, etc.
Hardware, Software for Traffic Surveillance	TM003	20	135	165	6.75	8.25	Processor and software.
Integration for Traffic Surveillance	TM032	20	225	275	11.25	13.75	Integration with other systems.
Hardware for Freeway Control	TM004	5	15	30			Includes 3 workstations.
Software, Integration for Freeway Control	TM007	5	180	220			Software and integration, installation and 1 year maintenance. Software is off-the-shelf technology and unit price does not reflect product development.
Labor for Freeway Control	TM005				225	275	Labor for operations (2 @ 50% of 100K) and maintenance technicians (2 @ 75K). Salary cost are fully loaded prices including base salary, overtime, overhead, benefits, etc.
Hardware for Lane Control	TM008	5	5.4	6.6	0.27	0.33	Includes 1 workstation and 19" monitor.
Software, Integration for Lane Control	TM009	10	225	275	11.25	13.75	Software development and integration and software upgrade for controllers. Software development is fine tune adjustments for local installations. Otherwise, software is COTS.
Labor for Lane Control	TM010				90	110	Labor for 2 operators @ 50% of 100K.
Software, Integration for Regional Control	TM011	10	300	440			Software and integration, installation and 1 year maintenance. Integration with other TMC's. Software is COTS.
Real-time, Traffic Adaptive Signal Control System		10	120	150	20		The cost range is based on commercially available packages, which run on a centralized computer. The high capital cost includes software packages for graphical user interface and incident management.
Labor for Regional Control	TM012				180	220	Labor for operators (2 @ 50% of 100K), transportation engineer (1 @ 50% of 100K), and maintenance contract. Salary costs are fully loaded prices including base salary, overtime, overhead, benefits, etc.
Video Monitors, Wall for Incident Detection	TM013	5	40.5	49.5	2.025	2.475	Includes 5 19" video monitors and video wall monitors (3x3=9 monitors w/switch, etc.).
Hardware for Incident Detection	TM014	5	81.7	119.3	4.085	5.965	Includes 4 servers, 5 workstations, and 2 laser printers.
Integration for Incident Detection	TM025	20	90	110	4.5	5.5	Integration with other systems.
Software for Incident Detection	TM015	5	90	110	4.5	5.5	Software is COTS and includes development cost
Labor for Incident Detection	TM016				630	770	Labor for operators (4 @ 100K and 1 manager @ 150K) and 2 maintenance techs @ 75K.
Video Monitor for Incident Response	TM017	5	2.7	3.3	0.135	0.165	Includes 1 19" monitor.
Hardware for Incident Response	TM018	5	2.7	3.3	0.135	0.165	Includes 1 workstation.

^ Applicable only to unit cost elements used in IDAS. * Not available for all unit cost elements.

Subsystem/Unit Cost Element	IDAS No.^	Lifetime* (years)	Capital Cost ($K)		O&M Cost ($K/year)		Notes
			Low	High	Low	High	
Transportation Management Center (TMC) ***continued***							
Integration for Incident Response	TM026	20	180	220			Integration with other systems.
Software for Incident Response	TM019	2	13.5	16.5	0.675	0.825	Software is COTS.
Labor for Incident Response	TM020				90	110	Labor for incident management coordinator (1 @ 100K).
Automated Incident Investigation System		5		15			Includes workstation, tripod, monopole antenna, Auto Integration, and AutoCAD software.
Hardware for Traffic Information Dissemination	TM021	5	5	10	0.25	0.5	Includes 1 workstation.
Software for Traffic Information Dissemination	TM022	5	18	22	0.9	1.1	Software is COTS.
Integration for Traffic Information Dissemination	TM023	20	90	110	4.5	5.5	Integration with other systems.
Labor for Traffic Information Dissemination	TM024				90	110	Labor for 1 operator @ 100K. Salary costs are fully loaded and include base salary, overtime, overhead, benefits, etc.
Software for Dynamic Electronic Tolls	TM027	5	22.5	27.5	1.125	1.375	Includes software installation and 1 year maintenance. Software is COTS.
Integration for Dynamic Electronic Tolls	TM028	20	90	110	4.5	5.5	Integration with other systems.
Hardware for Probe Information Collection	TM033	3	5	10	0.5	1	Includes 1 workstation.
Software for Probe Information Collection	TM034	5	18	22	1.8	2.2	Includes software installation and 1 year maintenance. Software is COTS.
Integration for Probe Information Collection	TM035	20	135	165	13.5	16.5	Integration with other systems.
Labor for Probe Information Collection	TM036				45	55	Labor for 1 operator (4 hours per day @ 100K/year). Salary costs are fully loaded prices and include base salary, overtime, overhead, benefits, etc.
Software for Rail Crossing Monitor	TM037	5	18	22	1.8	2.2	Includes software installation and 1 year maintenance. Software is COTS.
Integration for Rail Crossing Monitor	TM038	20	90	110			Integration with other systems.
Labor for Rail Crossing Monitor	TM039				45	55	Operators (1 @ 50% of 100K). Salary costs are fully loaded prices including base salary, overtime, overhead, benefits, etc.
Road Weather Information System (RWIS)		25		25	0.4	2.5	An RWIS consists of several components: environmental sensing stations (ESS), CPU, workstation with RWIS software, and communications equipment. All components of the RWIS reside at the TMC with the exception of the ESS. Detection subsystem for costs of ESS. See Roadside Cost of the ESS ($10K-$50K) should be added to $25K listed here in order to cost out the entire system. CPU replaced every 5 years at a cost of $4K. O&M cost range include communication, and optional weather forecast/meteorological service.

^ Applicable only to unit cost elements used in IDAS. * Not available for all unit cost elements.

Appendix A: ITS Unit Cost Database

Subsystem/Unit Cost Element	IDAS No.^	Lifetime* (years)	Capital Cost ($K)		O&M Cost ($K/year)		Notes
			Low	High	Low	High	
Transit Management Center (TR)							
Basic Facilities, Comm for Large Area	TR014		4000	4000	400	600	For population >750,000. Based on purchase of building rather than leasing space. Communications includes communications equipment internal to the facility such as equipment racks, multiplexers, modems, etc.
Basic Facilities, Comm for Medium Area	TR015		3200	3200	400	480	For population <750,000 and >250,000. Based on purchase of building rather than leasing space. Communications includes communications equipment internal to the facility such as equipment racks, multiplexers, modems, etc.
Basic Facilities, Comm for Small Area	TR016		2800	2800	400	420	For population <250,000. Based on purchase of building rather than leasing space. Communications includes communications equipment internal to the facility such as equipment racks, multiplexers, modems, etc.
Transit Center Hardware	TR001	10	15	30			Includes 3 workstations.
Transit Center Software, Integration	TR002	20	815	1720	6	12	Includes vehicle tracking & scheduling, database & information storage, schedule adjustment software, real time travel information software, and integration. Software is COTS.
Transit Center Additional Building Space	TR003				6	9	Additional space required for ITS technology - $12 - $18/sq. ft., 500 sq. ft.
Transit Center Labor	TR004				50	250	Labor for 3 staff @ 75K. Salary cost are fully loaded prices including base salary, overtime, overhead, benefits, etc.
Upgrade for Auto. Scheduling, Run Cutting, or Fare Payment	TR005	20	20	40	0.4	0.8	Processor/software upgrade, installation and 1 yr. maintenance (for processor). Software is COTS.
Integration for Auto. Scheduling, Run Cutting, or Fare Payment	TR012	20	225	500			Integration with other systems.
Further Software Upgrade for E-Fare Payment	TR013	20	40	60	0.8	1.2	Software upgrade. Software is COTS.
Vehicle Location Interface	TR007	20	10	15			Vehicle location interface.
Vehicle Location Equipment				275		16.5	
Video Monitors for Security System	TR008	10	15	20	0.75	1	Five per site.
Hardware for Security System	TR009	10	55	90	1.1	1.8	Includes 1 server and 3 workstations.
Integration of Security System with Existing Systems	TR010	20	250	500			Integration with other systems.
Labor for Security System	TR011				202	247	Labor for 3 staff @ 75K each. Salary cost are fully loaded prices including base salary, overtime, overhead, benefits, etc.
Toll Administration (TA)							
Toll Administration Hardware	TA001	5	10	15	1	1.5	Includes Pentium PC with 1G hard drive, 2 workstations, printer, and modem.
Toll Administration Software	TA002	10	40	80	4	8	Includes local database and national database coordination. Software is COTS.
Transit Vehicle On-Board (TV)							
Driver Interface and Schedule Processor	TV001	10	0.3	0.5	0.006	0.01	On-board schedule processor and database.
Cell Based Communication Equipment	TV002	10	0.15	0.25	0.0075	0.0125	Cell-based radio with data capacity.

^ Applicable only to unit cost elements used in IDAS. * Not available for all unit cost elements.

Subsystem/Unit Cost Element	IDAS No.^	Lifetime* (years)	Capital Cost ($K)		O&M Cost ($K/year)		Notes
			Low	High	Low	High	
Transit Vehicle On-Board (TV) ***continued***							
GPS/DGPS for Vehicle Location	TV003	10	0.5	0.8	0.01	0.016	AVL GPS/DGPS.
Signal Preemption Processor	TV004	10	0.3	0.6	0.006	0.01	On-board schedule processor and database. Complement to IDAS elements RS004 and RS005.
Signal Preemption/Priority Emitter			0.5	2.1			Data-encoded emitter; manually initiated. Complement to Roadside Signal Preemption/ Priority (see Roadside Control subsystem).
Preemption/Priority Transponder				0.075			Passive transponder mounted on underside of transit vehicle. Requires transit priority system at the Transit Management Center.
Trip Computer and Processor	TV005	10	0.1	0.15	0.002	0.003	On-board processor for trip reporting and data storage.
Security Package	TV006	10	4.2	5.3	0.21	0.265	On-board CCTV surveillance camera and hot button.
Electronic Farebox	TV007	10	0.8	1.5	0.04	0.075	On-board flex fare system DBX processor, on-board farebox, and smart card reader.
Commercial Vehicle Administration (CA)							
Commercial Vehicle Admin Hardware	CA001	10	15	30	0.3	0.6	Includes 3 workstations.
Commercial Vehicle Admin Software, Integration	CA002	20	200	220	4	4.4	Includes processor and integration. Software is COTS .
Commercial Vehicle Admin Labor	CA003				270	330	Labor for 4 staff @ 75K (average). Salary costs are fully loaded prices including base salary, overtime, overhead, benefits, etc.
Software Upgrade for Electronic Credential Purchasing, Mgt.	CA004	20	60	140	1.2	2.8	Electronic credentials purchase software, database and management for post-trip processing & E-credentials.
Software Upgrade for Inter-Agency Info Exchange	CA005	20	20	40	0.4	0.8	Processor and integration add-on. Software is COTS.
Added Labor for Inter-Agency Info Exchange	CA006				67	82	Labor for 1 staff @ 75K (average). Salary costs are fully loaded prices including base salary, overtime, benefits, etc.
Software Upgrade for Safety Administration	CA007	20	40	80	0.8	1.6	Database add-on, software, and integration. Software is COTS.
Commercial Vehicle Check Station (CS)							
Check Station Structure	CC001	20	50	75			Roadside structure - mainline w/lane indicator signals.
Signal Board	CC002	10	10	15	1	1.5	Roadside signal board.
Signal Indicator	CC003	20	5	10	0.25	0.5	Signal indicator system.
Roadside Beacon	CC004	10	5	8	0.5	0.8	Roadside beacon used for electronic screening (not included in roadside subsystem). Beacon repair/replacement maintenance.
Wireline to Roadside Beacon	CC005	20	10	20			Dedicated wireline communication from beacon to roadside (1 mile upstream).
Check Station Software, Integration	CC006	20	180	215			Software, processor and integration.
Check Station Hardware	CC007	10	0.3	0.5	0.006	0.01	Includes 1 workstation.
Detection System	CC008	10	50	75	2.5	3.75	Commercial vehicle communication interface and communication device (cell-based radio).

^ Applicable only to unit cost elements used in IDAS. * Not available for all unit cost elements.

Subsystem/Unit Cost Element	IDAS No.^	Lifetime* (years)	Capital Cost ($K)		O&M Cost ($K/year)		Notes
			Low	High	Low	High	
Commercial Vehicle Check Station (CS) ***continued***							
Software Upgrade for Safety Inspection	CC009	20	40	80	0.8	1.6	Safety-database add-on, and result writing to vehicle tag processor add-on. Software is COTS.
Handheld Safety Devices	CC010	5	3	5	0.3	0.5	For commercial vehicle inspection. The devices either measure data themselves or read data from the vehicle. Three per location.
Software Upgrade for Citation and Accident Recording	CC011	20	20	40	1	2	Software add-on for recording of citation and accident information to the commercial vehicle.
Weigh-In-Motion Facility	CC012	10	14	21	1.4	2.1	Includes WIM fixed-load cell and interface to roadside facility. Software is COTS.
Wireline to Weigh-In-Motion Facility	CC013	10	1	2	0.1	0.2	Wireline communication (local line).
Commercial Vehicle On-Board (CV)							
Electronic ID Tag	CV001	10	0.65	1.1	0.013	0.022	Includes ID tag, additional software & processing, and database storage. Software is COTS.
Communication Equipment	CV002	10	1.15	2.25	0.0075	0.0125	Commercial vehicle communication interface and communication device (cell-based radio).
Central Processor and Storage	CV003	10	0.3	0.5	0.006	0.01	Equipment on board for the processing and storage of cargo material.
GPS/DGPS	CV004	10	0.3	0.5	0.006	0.01	GPS for vehicle location.
Driver and Vehicle Safety Sensors, Software	CV005	10	1.1	2.2	0.04	0.08	Additional software and processor for warning indicator and audio system interface, and onboard sensors for engine/vehicle and driver. Software is COTS.
Cargo Monitoring Sensors and Gauges	CV006	10	0.17	0.35	0.017	0.035	Optional on-board sensors for measuring temperature, pressure, and load leveling.
Fleet Management Center (FM)							
Fleet Center Hardware	FM001	10	15	30	0.3	0.6	Costs include 3 workstations.
Fleet Center Software, Integration	FM002	20	215	500			Includes processor and integration. Software is COTS.
Fleet Center Labor	FM003				337	412	Labor for 5 staff @ 75K. Salary costs are fully loaded prices including base salary, overtime, overhead, benefits, etc.
Software for Electronic Credentialing, Clearance	FM004	20	80	180			Includes electronic credential purchase software, database and management for trip reports, and database management for preclearance. Software is COTS.
Software for Tracking and Scheduling	FM005	20	40	100	4	10	Vehicle tracking and scheduling. Software is COTS.
Vehicle Location Interface	FM006	20	10	15			Vehicle location interface from FMS to TMS.
Software Upgrade for Fleet Maintenance	FM007	20	20	40	0.4	0.8	Processor/software upgrade to add capability to automatically generate preventative maintenance schedules from vehicle mileage data. Software is COTS.
Integration for Fleet Maintenance	FM008	20	100	200	2	4	Integration with other systems.
Software Upgrade for HAZMAT Management	FM009	20	20	40	0.4	0.8	Vehicle tracking & scheduling enhancement. Software is COTS.
Hardware Upgrade for HAZMAT Management	FM010	10	5	10	0.1	0.2	Includes 1 workstation.

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Subsystem/Unit Cost Element	IDAS No.^	Lifetime* (years)	Capital Cost ($K)		O&M Cost ($K/year)		Notes
			Low	High	Low	High	
Vehicle On-Board (VS)							
Communication Equipment	VS001	7	0.2	0.4	0.004	0.008	Wireless data transceiver.
In-Vehicle Display	VS002	7	0.05	0.1	0.001	0.002	In-vehicle display/warning interface. Software is COTS.
In-Vehicle Signing System	VS003	7	0.16	0.4	0.0032	0.008	Interface to active tag reader, processor for active tag decode, and display device for messages.
GPS/DGPS	VS004	7	0.25	0.5	0.005	0.01	Global Positioning System/Differential Global Positioning Systems.
GIS Software	VS005	7	0.2	0.3			Geographical Information System (GIS) software for performing route planning.
Route Guidance Processor	VS006	7	0.1	0.15	0.002	0.003	Limited processor for route guidance functionality.
Sensors for Lateral Control	VS007	7	0.8	1.1	0.016	0.022	Includes lane sensors in vehicle and lateral sensors MMW radar.
Electronic Toll Equipment	VS008	7	0.04	0.1			Active tag interface and debit/credit card interface.
Mayday Sensor and Processor	VS009	7	0.15	0.65	0.003	0.013	Collision-detector sensor and interface for Mayday processor. Software is COTS.
Sensors for Longitudinal Control	VS010	7	0.3	0.5	0.006	0.01	Longitudinal sensors MMW radar.
Advanced Steering Control	VS011	7	0.5	0.6	0.01	0.012	Advanced steering control ("hands off" driving). Software is COTS.
Advanced Cruise Control	VS012	7	0.15	0.3	0.003	0.006	Adaptive cruise control (automatic breaking and accelerating).
Intersection Collision Avoidance Processor, Software	VS013	7	0.28	0.55	0.0056	0.011	Software/processor for infrastructure transmitted information, interface to in-vehicle signing and audio system, software and processor to link to longitudinal and lateral vehicle control modules based on input signal from vehicle intersection collision warning equipment package. Software is COTS.
Vision Enhancement System	VS014	7	1.2	2.2	0.06	0.11	In-vehicle camera, software & processor, heads-up display, and infrared sensors (local sensor system). Software is COTS.
Driver and Vehicle Safety Monitoring System	VS015	7	0.66	1.25	0.033	0.0625	Safety collection processor and software, driver-condition sensors, six vehicle-condition sensors (@ $50 each), and vehicle data storage. Software is COTS.
Pre-Crash Safety System	VS016	7	1.1	2.15	0.037	0.067	Vehicle condition sensors, vehicle performance sensors, software/processor, interface, pre-crash safety systems deployment actuators. Software is COTS.
Software, Processor for Probe Vehicle	VS020	7	0.05	0.15	0.001	0.003	Software and processor for communication to roadside infrastructure, signal generator, message generator. Software is COTS.
Active Tag		7	0.02	0.05	0.002	0.005	Vehicle tag that can be updated (writable).
Passive Tag		5		0.015			Read-only vehicle tag.
In-Vehicle Navigation System		7		2.8			COTS product that includes in-vehicle display and supporting software.

^ Applicable only to unit cost elements used in IDAS. * Not available for all unit cost elements.

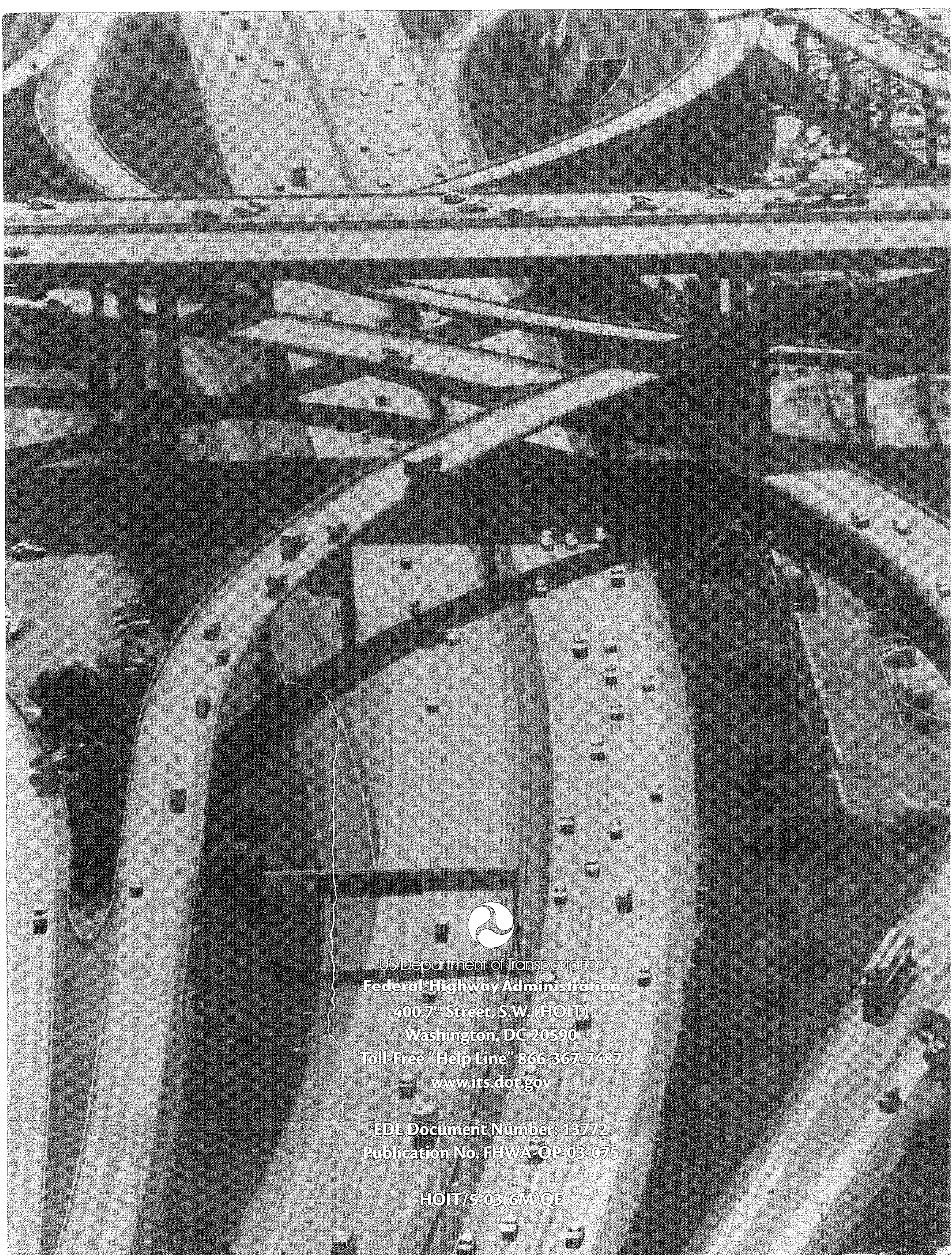
Subsystem/Unit Cost Element	IDAS No.^	Lifetime* (years)	Capital Cost ($K)		O&M Cost ($K/year)		Notes
			Low	High	Low	High	
Personal Devices (PD)							
Basic PDA	PD001	7	0.2	0.4	0.005	0.008	Personal digital assistant.
Advanced PDA for Route Guidance, Interactive Information	PD002	7	0.5	0.75	0.01	0.015	Personal digital assistant with advanced capabilities (route guidance, interactive).
Modem Interface, Antenna for PDA	PD003	7	0.18	0.25	0.0036	0.005	Modem interface and separate antenna for wireless capability.
PDA with Wireless Modem		2	0.2	0.6	0.12	0.3	Personal digital assistant with wireless modem. O&M based on monthly subscriber rate plans of 50 Kbytes (low) and 150 Kbytes (high).
Software Upgrade for Interactive Information		7	0.1	0.2	0.002	0.004	Software is COTS.
GPS/DGPS	PD005	7	0.5	0.8	0.025	0.04	GPS/DGPS.
GIS Software	PD006	7	0.1	0.15	0.005	0.0075	Additional GIS/GUI capability.

^ Applicable only to unit cost elements used in IDAS. * Not available for several equipment or subsystems.

Appendix B: List of Acronyms

ABBCS	Ambassador Bridge Border Crossing System
ACN	Automatic Collision Notification
ADMS	Archived Data Management System
ADUS	Archived Data User Service
APTS	Advanced Public Transportation Systems
ARTIC	Advanced Rural Transportation Information and Coordination
ARTIMIS	Advanced Regional Traffic Interactive Management and Information Systems
ATAF	American Trucking Association Foundation
ATIS	Advanced Traveler Information System
ATM	Automatic Teller Machine
ATMS	Advanced Traffic Management System
AVI	Automatic Vehicle Identification
AVL	Automated Vehicle Location
AWARD	Advanced Warning for Railroad Delays
B/C	Benefit/Cost
CA	Commercial Vehicle Administration
CAD	Computer Aided Dispatch
CC	Commercial Vehicle Check Station
CCS	Collision Countermeasure System
CCTV	Closed Circuit Television
CDOT	Colorado Department of Transportation
CHART	Coordinated Highways Action Response Team
CLEOPATRA	City Laboratories Enabling Organization of Particularly Advanced Telematics Research and Assessments
CO	Carbon Monoxide
CTA	Chicago Transit Authority
CV	Commercial Vehicle On-Board
CVAP	Commercial Vehicle Administrative Processes
CVIEW	Commercial Vehicle Information Exchange Window
CVISN	Commercial Vehicle Information Systems and Network
CVO	Commercial Vehicle Operations
CWS	Collision Warning System
DMS	Dynamic Message Sign
DOT	Department of Transportation
EDI	Electronic Data Interchange
EMS	Emergency Medical Services
EMT	Emergency Medical Technician
EOC	Emergency Operations Center
EPA	Environmental Protection Agency
E-PASS	Express Pass
ER	Emergency Response Center
ESS	Environmental Sensing Station
ETC	Electronic Toll Collection
EV	Emergency Vehicle On-Board
FAST	Freeway and Arterial System of Transportation
FHWA	Federal Highway Administration
FM	Fleet Management
FOT	Field Operational Test
FY	Fiscal Year
GIS	Geographical Information System
GPS	Global Positioning System
GYRITS	Greater Yellowstone Rural Intelligent Transportation Systems
HAR	Highway Advisory Radio
HC	Hydrocarbon
HOV	High Occupancy Vehicle
HRI	Highway-Rail Intersections
HUT	Highway User Tax
ICC	Intelligent Cruise Control

IFTA	International Fuel Tax Agreement
IH	Interstate Highway
IRP	International Registration Plan
ISP	Information Service Provider
ISS	Inspection Selection Systems
ITDA	Independent Truckers and Drivers Association
ITE	Institute of Transportation Engineers
ITS	Intelligent Transportation Systems
ITS/CVO	ITS for Commercial Vehicles Operations
IVN	In-Vehicle Navigation
IVS	In-Vehicle Systems
JPO	Joint Program Office
LADOT	Los Angeles Department of Transportation
MDI	Model Deployment Initiative
MDT	Mobile Data Terminal
MMDI	Metropolitan Model Deployment Initiative
MMTA	Maryland Motor Transportation Authority
Mn/DOT	Minnesota Department of Transportation
MTA	Metropolitan Transportation Authority
NHTSA	National Highway Traffic Safety Administration
NJTA	New Jersey Turnpike Authority
NOx	Oxides of Nitrogen
O&M	Operations & Maintenance
OSCAR	One-Stop-Credentialing and Registration
PC	Personal Computer
PD	Personal Devices
PDA	Personal Digital Assistant
PM	Parking Management
PSAP	Public Safety Answering Point
PTC	Projected-Times-to-Collision
PuSHMe	Puget Sound Help Me (Mayday System)
RDT	Regional Transportation District
RM	Remote Location
ROUTES	Rail, Omnibus, Underground, Travel Enquiry System
RS-C	Roadside Control
RS-D	Roadside Detection
RS-I	Roadside Information
RS-RC	Roadside Rail Crossing
RS-TC	Roadside Telecommunications
RWIS	Road Weather Information System
SAFER	Safety and Fitness Electronic Record
SCOOT	Split Cycle Offset Optimization Techniques
SEMSIM	Southeast Michigan Snow and Ice Management
SIE	Safety Information Exchange
SSRS	Single State Registration System
TA	Toll Administration
TCC	Traffic Control Centers
TM	Transportation Management Center
TP	Toll Plaza
TR	Transit Management Center
TRANSMIT	TRANSCOM's System for Managing Incidents and Traffic
T-REX	Transportation Expansion
TV	Transit Vehicle On-Board
USD	United States Dollars
U.S. DOT	United States Department of Transportation
VS	Vehicle On-Board
VSL	Variable Speed Limit
WIM	Weight in Motion
WSDOT	Washington State Department of Transportation



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